Miscellaneous Paper SL-95-5
December 1995

US Army Corps of Engineers
Waterways Experiment Station

Evaluation of Concrete Seawalls at Perry's Victory and International Peace Memorial

by Roy L. Campbell, Sr., G. Sam Wong

Prepared for Headquarters, U.S. Army Corps of Engineers

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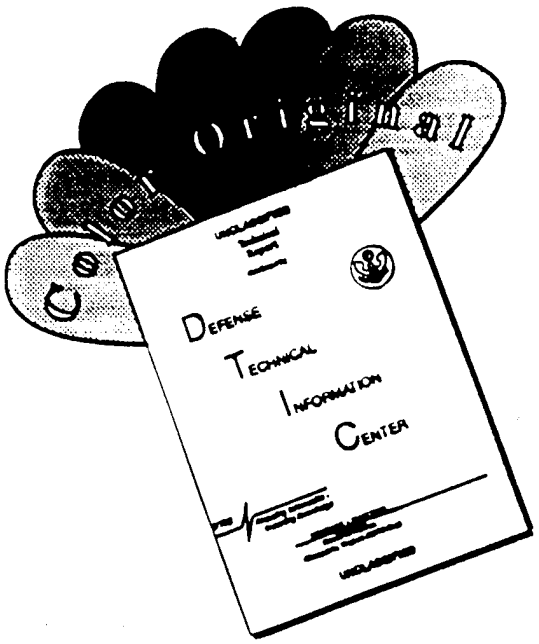

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Waterways Experiment Station
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Final report

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Prepared for U.S. Army Corps of Engineers
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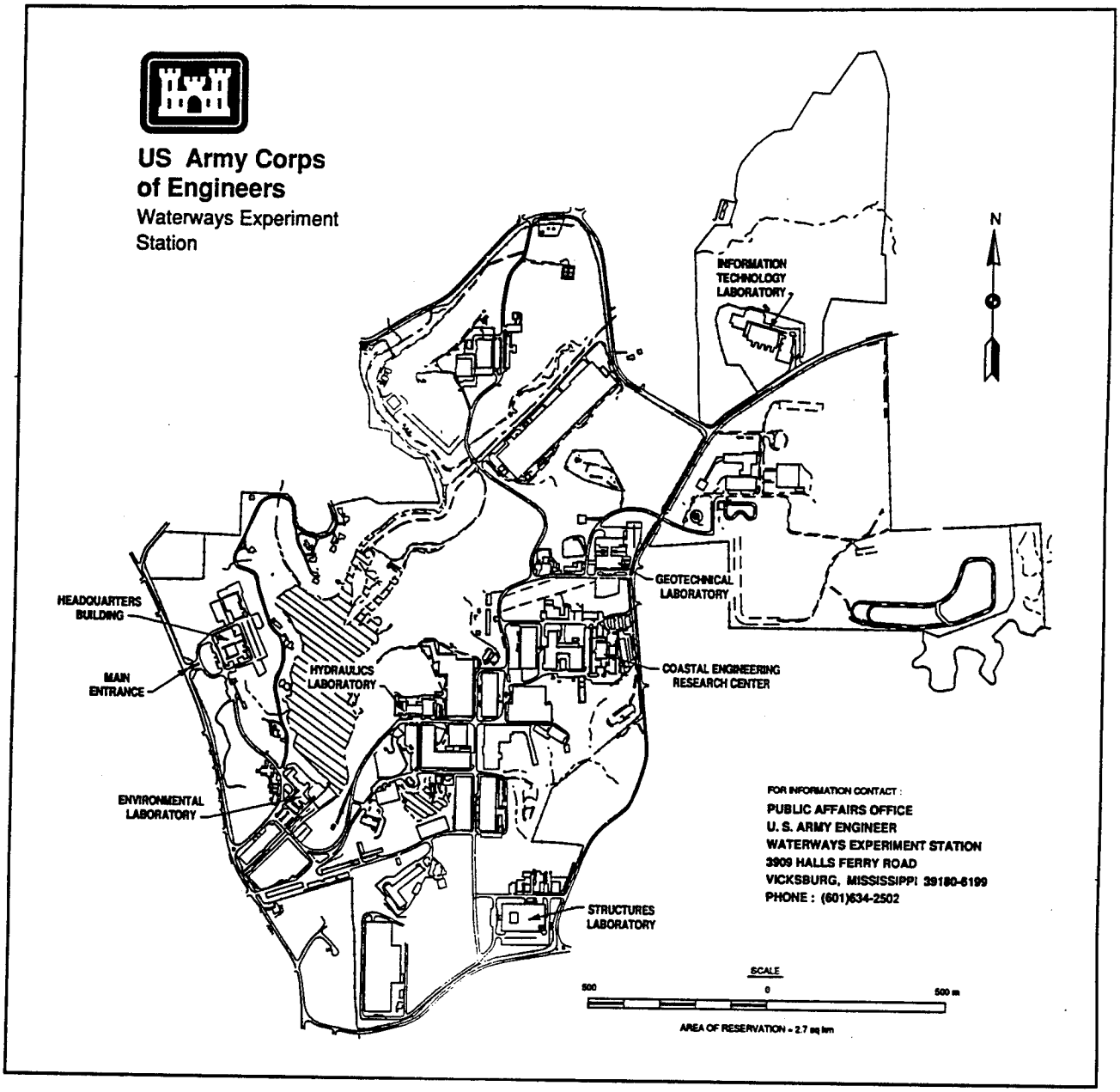


Waterways Experiment Station Cataloging-in-Publication Data

Campbell, Roy L.

Evaluation of concrete seawalls at Perry's Victory and International Peace Memorial / by Roy L. Campbell, Sr., G. Sam Wong ; prepared for U.S. Army Corps of Engineers.

134 p. : ill. ; 28 cm. -- (Miscellaneous paper ; SL-95-5)

Includes bibliographic references.

1. Flood control -- Ohio -- Put-in-Bay. 2. Memorials -- Ohio. 3. Concrete walls. 4. Concrete -- Deterioration. I. Wong, G. Sam. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Structures Laboratory (U.S. Army Engineer Waterways Experiment Station) V. Title. VI. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-95-5.

TA7 W34m no.SL-95-5

Contents

Preface

The work described in this report was conducted for the U.S. Army Engineer District, Buffalo, and was part of an evaluation being performed for the U.S. Department of the Interior, National Park Service. This work was authorized by Military Interdepartmental Purchase Request (MIPR) NCB-MR-95-27EF. Messrs. Frank Lewandowski and Jon Kolber were the project points of contact for the Buffalo District. Mr. Ted Hillmer was the project point of contact for the National Park Service. Mr. Richard A. Lusardi, Superintendent at Perry's Victory and International Peace Memorial, was the field point of contact for National Park Service.

Mr. James E. McDonald was the principal investigator for the Structures Laboratory (SL), U.S. Army Engineer Waterways Experiment Station (WES). The report was prepared by Messrs. Roy L. Campbell, Sr., and G. Sam Wong, Concrete Technology Division, CTD. Mr. Campbell performed the visual inspection of the seawalls and selected coring locations. Mr. A. Michael Alexander, CTD, helped plan the nondestructive investigation, and Mr. Dan E. Wilson, CTD, made the ultrasonic pulse velocity measurements. Coring of concrete and testing of cores in compression were performed by Mr. Jimmy W. Hall III, CTD. The petrographic analysis was performed by Mr. Wong. The work was conducted under the general supervision of Mr. William F. McCleese, Acting Chief, CTD, and Mr. Bryant Mather, Director, SL.

Dr. Robert W. Whalin was Director of WES during the performance of this work. COL Bruce K. Howard, EN, was Commander.

1 Introduction

Background

Perry's Victory and International Peace Memorial is located at Put-In-Bay, Ohio on South Bass Island in Lake Erie and is maintained and operated by the National Park Service. To protect the memorial from wave erosion damage, a seawall was constructed along the north shoreline. In 1977-78, the north seawall was modified to increase its elevation and length and a second seawall constructed along the south shoreline.

On 11 October 1994, Mr. Frank Lewandowski of the Army Engineer District, Buffalo conducted a visual inspection of the seawalls and found areas of distress and deterioration in the concrete. Based on this inspection, it was concluded that remedial action would probably be necessary sometime in the future and that a more extensive evaluation was required to determine the cause(s) of distress and deterioration and to detail remedial actions required.

The U.S. Army Corps of Engineer Waterways Experiment Station was requested in spring of 1995 to evaluate the concrete in the seawalls and to report the cause(s) and extent of concrete deterioration and proposed remedial procedures.

Seawalls

The north seawall contains 60 monoliths and has an approximate length of 580 m (1900 ft). Monoliths 1-17 and 42-60 are extensions to the old seawall and vary in length between 4.6 and 7.6 m (15 and 25 ft). Monoliths 18-41 are a part of the old seawall and are 15.2 m (50 ft) long.

The south seawall contains 73 monoliths and has an approximate length of 460 m (1500 ft). Most monoliths are 6.1 m (20 ft) long, except for a few that are 6.7 m (22 ft) long.

Lengths for monoliths were estimated from distances given in Appendix A, Tables A-1 and A-2 (Pulse Velocity Measurements).

Monolith Numbering

The monoliths for the north seawall were designated from east to west starting with monolith N1 and ending with N60. The monoliths for the south seawall were designated from west to east starting with monolith S1 and ending with monolith S73.

2 Field Evaluation

During the period 16-22 May 1995, a team from WES performed a visual and photographic examination of accessible concrete surfaces, made ultrasonic pulse velocity measurements across the top portion of walls, and took cores from the tops of seawalls in both distressed and nondistressed areas.

Visual Inspection

North Seawall

A visual inspection of the north seawall found that most of the distress and deterioration in the concrete was observed at the vertical joints. At a few of the joints, the distress was observed at both corners of the top surface and in the landside face (Figures 1 and 2). Localized distress was observed in the form of hairline cracks with a reddish-brown stain coming from some of the cracks at the ladder recess of monolith N22 (Figure 3). Moisture was retained in some of the aggregate visible in the surface of new borings (Figure 4).

There were a number of minor areas of distress observed along the north seawall. The distress appeared in the form of hairline cracks, staining, and popouts. Small areas of reddish-brown stains were observed coming from some of the random and traverse cracks.

All joint seals showed varying degrees of damage, deterioration, and adhesive and cohesive failures. At a few joints, the seal and filler materials were completely missing. Adjacent monolith ends at joints 3/4 through 6/7, 8/9 through 11/12, 13 /14 through 16/17, 42/43 through 44/45, 46/47 through 50/51, 52/53 through 55/56, and 57/58 through 59/60 were cast against each other. These joints had an approximate 2-in.-deep slot for joint sealant material.

South Seawall

A visual inspection of the south seawall found that most of the distress and deterioration in the concrete was observed along the top-lakeside edges at the vertical joints (Figures 5 - 8). Extensive cracking was observed in the tops of four monoliths, S7, S16, S17, and S20 (Figures 9 -14). Areas of reddish-brown stains were observed coming from cracking along a longitudinal plane in landside (Figures 10 and 11) and lakeside faces of these monoliths.

Moisture was retained in some of the aggregate visible in the surface of new borings (Figures 15 - 17).

There were numerous areas of minor distress in the form of hairline cracks, staining, and popouts. Small areas of reddish-brown stains were observed coming from random and traverse cracks.

All joint seals showed varying degrees of damage, deterioration, and adhesive and cohesive failures. At a few joints, the seal and filler materials were completely missing. Adjacent monolith ends at joints 1/2 through 4/5, 6/7 through 8/9, 10/11 through 13/14, 15/16 through 18/19, 20/21 through 22/23, 24/25 through 28/29, 30/31 through 38/39, 40/41 through 43/44, 45/46 through 48/49, 50/51 through 53/54, 55/56 through 58/59, 60/61 through 63/64, 65/66 through 68/69, and 70/71 through 72/73 were cast against each other (Figure 17). These joints had an approximate 2-in.-deep slot for joint sealant material.

Concrete Coring

Cores were obtained from a total of 24 locations (9 north seawall, 2 old seawall, and 13 south seawall). At three locations in the south seawall, the concrete broke up into such small pieces that a test core could not be retrieved. The core rig was moved landward at these locations and a second attempt made to obtain a test core. Three cores (N57, S8, and S68) were taken from areas that showed no distress. The results of coring are summarized in Tables 1 and 2.

Pulse Velocity Measurements

Ultrasonic pulse velocity measurements were performed in accordance with ASTM C 597 and taken at locations approximately 150 mm (6 in.) below the top of seawalls at 1.5 m (5 ft) intervals along the length of each monolith.

The resulting measurements are given in Appendix A.

A suggested scale for estimating the quality of the concrete using pulse velocity measurements (Leslie and Cheesman 1949) is given as follows:

Ultrasonic Pulse Velocity, m/s (ft/s)	Quality of Concrete
> 4,570 (15,000)	Excellent
3,660 - 4,570 (12,000 - 15,000)	Good
3,050 - 3,660 (10,000 - 12,000)	Questionable
2,130 - 3,050 (7,000 - 10,000)	Poor
< 2,130 (7,000)	Very Poor

A total of 66 locations (29 north seawall and 37 south seawall) where low pulse velocity readings were recorded are listed in Tables 3 and 4. All low readings were within 1.5 m (5 ft) of a joint, except for those taken in monoliths N24, S16, and S20. The low reading in N24 was suspected to be the result of a localized deficiency in the concrete.

Table 1
Field Notes on Coring of North Seawall

Core Location		Description of Core
Monolith	Reference Point	
N10	North seawall joint 9/10	Rubble
N11	North seawall joint 11/12	Core length = 356 mm (14 in.)
N21	North seawall, near midlength of monolith	Core length = 483 mm (19 in.)
N22	North seawall joint at ladder recess	Core length = 432 mm (17 in.)
N30	North seawall joint 29/30	Core length = 381 mm (15 in.)
N38	North seawall joint 37/38	Core length = 190 mm (7-1/2 in.)
N45	North seawall joint 44/45	Core length = 384 mm (15-1/8)
N56	North seawall joint 56/57	Core length = 432 mm (17 in.)
N57	North seawall joint 57/58	Core length = 426 mm (16-3/4 in.)
N34*	North seawall joint 34/35	Rubble
N40*	North seawall joint 40/41	Core length = 102 mm (4 in.)

*Specimens taken from exposed landside top of old seawall at monolith location in new seawall.

Table 2
Field Notes on Coring of South Seawall

Core Location		Description of Core
Monolith	Reference Point	
S7	South seawall joint 7/8	Core length = 76 mm (3 in.)
S8	South seawall, near joint 7/8	Core length = 483 mm (19 in.)
S16	South seawall joint 15/16	Core length = 102 mm (4 in.)
S16/17	South seawall at joint 16/17	Core length = 190 mm (7-1/2 in.)
S17A	South seawall joint 17/18	Rubble
S17B	South seawall joint 17/18 (approximately 152 mm (6 in.) landward from S17A)	Core length = 375 mm (14-3/4 in.)
S20	South seawall joint 19/20	Core length = 76 mm (3 in.)
S27	South seawall joint 27/28	Core length =102 and 330 mm (4 and 13 in. lengths)
S37	South seawall joint 37/38	Core length = 381 mm (15 in.)
S49	South seawall joint 48/49	Core length =165 mm (6-1/2 in.)
S52A	South seawall joint 1/52	Rubble
S52B	South seawall joint 51/52 (approximately 152 mm (6 in.) landward from S52A)	Core length = 292 mm (11-1/2 in.)
S60A	South seawall joint 59/60	Core length =152 mm (6 in.)
S60B	South seawall joint 59/60 (approximately 152 mm (6 in.) landward from S60A)	Core length = 413 mm (16-1/4 in.)
S68	South seawall joint, near midlength of monolith	Core length = 356 mm (14 in.)
S72	South seawall joint 72/73	Core length = 419 mm (16-1/2 in.)

Table 3
North Seawall Locations Where Low Pulse Velocity Measurements were Recorded

Location		Pulse Velocity m/s (ft/s)	Location		Pulse Velocity m/s (ft/s)
Monolith	Distance From East End of Monolith m (ft)		Monolith	Distance From East End of Monolith m (ft)	
N6	0.08 (0.25)	2918 (9573)	N21	0.08 (0.25)	2272 (7453)
N7	0.08 (0.25)	2052 (6731)	N22	0.08 (0.25)	ERR
N8	6.10 (20.00)	2667 (8750)	N22	1.52 (5.00)	2223 (7292)
N9	0.08 (0.25)	2223 (7292)	N23	14.55 (47.75)	3419 (11218)
N9	6.10 (20.00)	2886 (9470)	N24	7.62 (25.00)	2646 (8681)
N10	0.08 (0.25)	ERR	N27	0.08 (0.25)	3334 (10938)
N10	6.10 (20.00)	ERR	N29	0.08 (0.25)	2223 (7292)
N11	0.08 (0.25)	ERR	N31	0.08 (0.25)	3252 (10671)
N11	5.94 (19.50)	ERR	N31	14.63 (48.00)	1905 (6250)
N12	0.08 (0.25)	2667 (8750)	N33	6.10 (20.00)	2287 (7504)
N14	0.08 (0.25)	2825 (9269)	N38	0.08 (0.25)	2540 (8333)
N14	6.10 (20.00)	2381 (7813)	N59	6.10 (20.00)	2020 (6629)
N18	0.08 (0.25))	1990 (6530)	N60	0.08 (0.25)	ERR
N19	14.63 (48.00)	3293 (10802)	N60	1.52 (5.00)	ERR
N20	0.08 (0.25)	2963 (9722)			

Table 4
South Seawall Locations Where Low Pulse Velocity Measurements were Recorded

Location		Pulse Velocity m/s (ft/s)	Location		Pulse Velocity m/s (ft/s)
Monolith	Distance From West End of Monolith m (ft)		Monolith	Distance From East End of Monolith m (ft)	
S1	6.02 (19.75)	1909 (6263)	S30	0.08 (0.25)	2623 (8607)
S7	0.08 (0.25)	3310 (10860)	S31	6.10 (20.00)	1702 (5585)
S7	1.52 (5.00)	3293 (10803)	S33	0.08 (0.25)	2229 (7312)
S16	0.08 (0.25)	ERR	S40	6.10 (20.00)	ERR
S16	1.52 (5.00)	2899 (9511)	S42	0.08 (0.25)	2036 (6679)
S16	3.05 (10.00)	2241 (7353)	S49	0.08 (0.25)	ERR
S16	4.57 (15.00)	2020 (6629)	S52	0.08 (0.25)	ERR
S16	6.10 (20.00)	2015 (6612)	S52	6.10 (20.00)	2052 (6731)
S17	4.57 (15.00)	ERR	S53	0.08 (0.25)	2241 (7353)
S17	5.64 (18.50)	ERR	S58	0.08 (0.25)	3239 (10628)
S18	1.52 (5.00)	3200 (10500)	S59	0.08 (0.25)	1861 (6105)
S18	6.10 (20.00)	1455 (4773)	S60	0.08 (0.25)	2931 (9615)
S20	0.08 (0.25)	ERR	S63	0.08 (0.25)	3362 (11029)
S20	1.52 (5.00)	ERR	S63	6.10 (20.00)	2500 (8203)
S20	3.05 (10.00)	ERR	S67	0.08 (0.25)	1591 (5219)
S20	4.57 (15.00)	ERR	S67	6.02 (19.75)	3266 (10714)
S20	6.10 (20.00)	ERR	S72	0.08 (0.25)	ERR
S27	1.52 (5.00)	ERR	S72	6.10 (20.00)	ERR
S29	3.05 (10.00)	3334 (10938)			

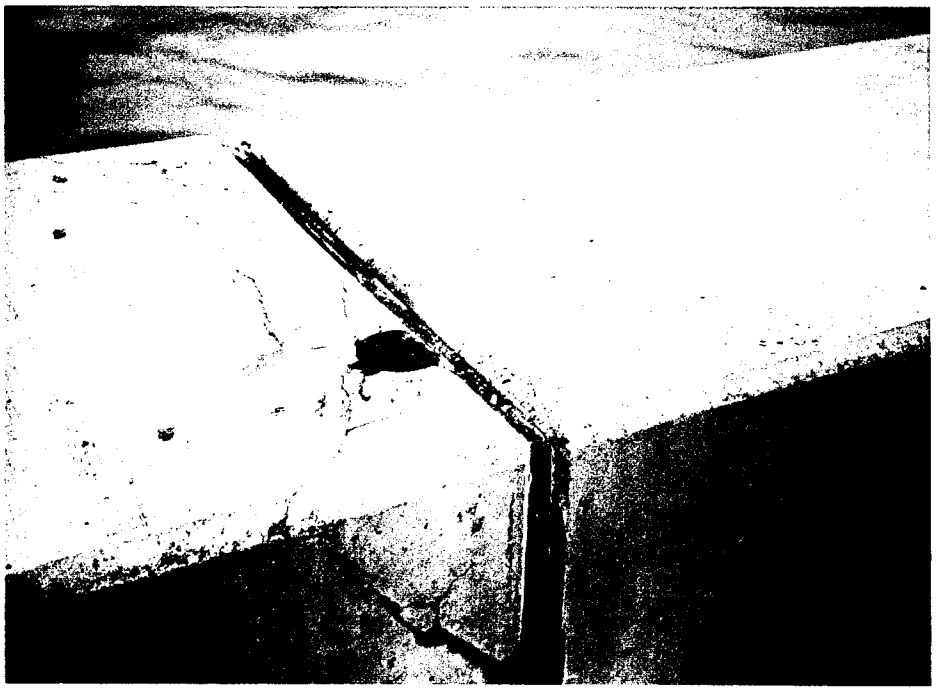


Figure 1. Cracking at joint 9/10, north seawall monolith N10

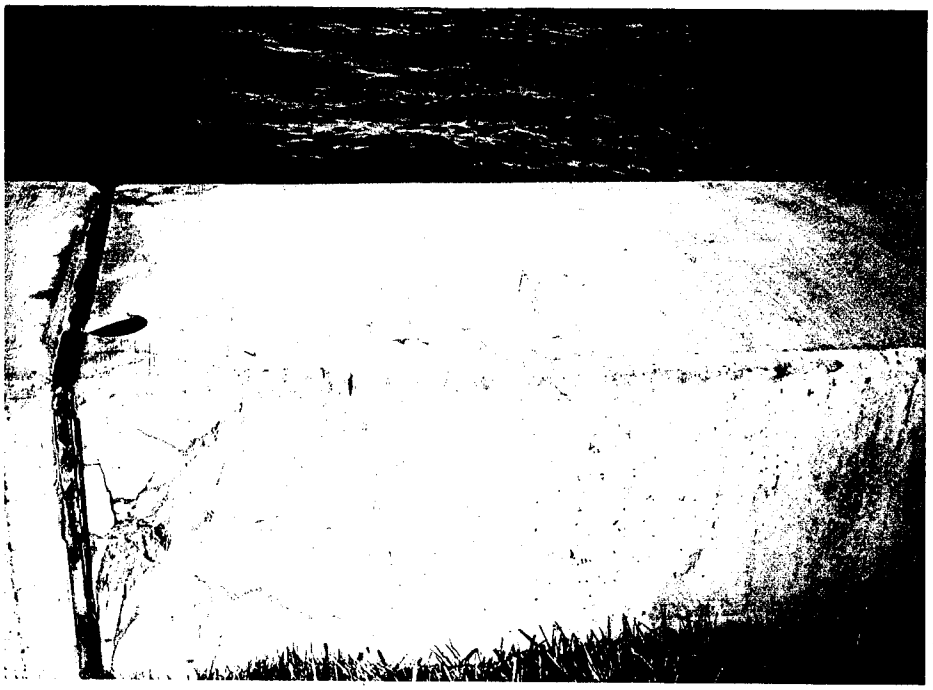


Figure 2. Cracking at joint 11/12, north seawall monolith N11

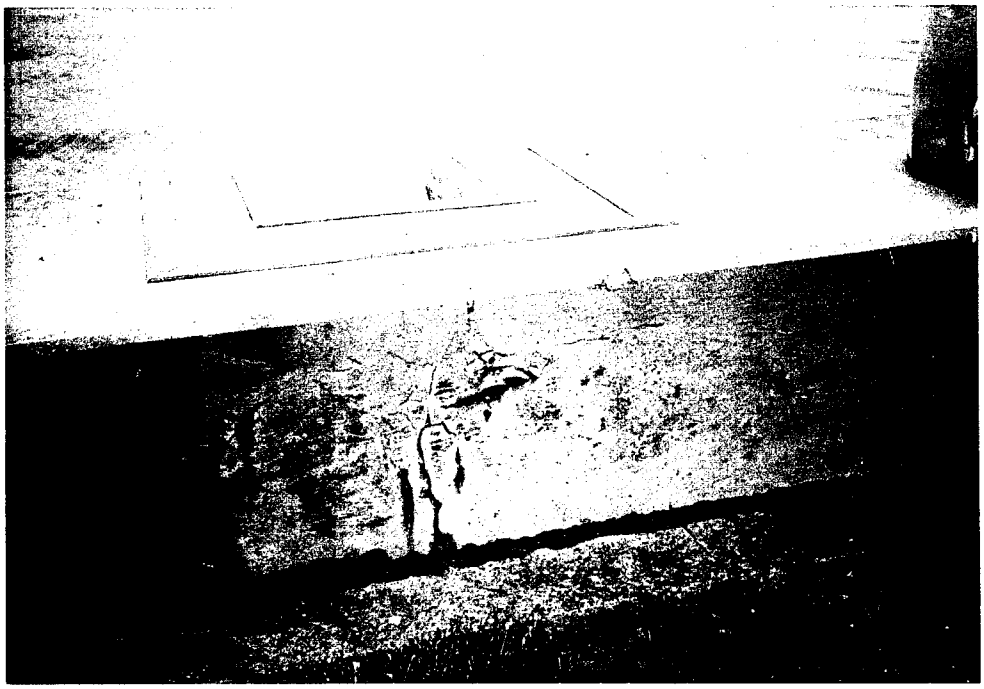


Figure 3. Hairline cracks with reddish-brown stains at ladder recess, north seawall monolith N22

Figure 4. Moisture retained in and around some of the aggregate particles visible in the surface of boring at joint 37/38, north seawall monolith N38

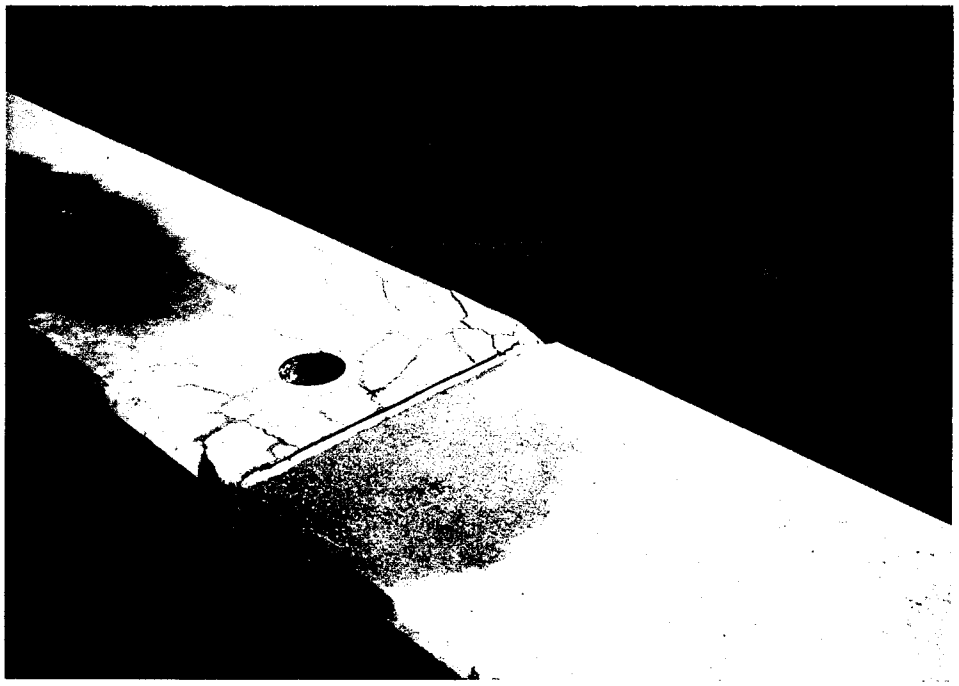


Figure 5. Cracking along lakeside edge at joint 48/49, south seawall monolith S49

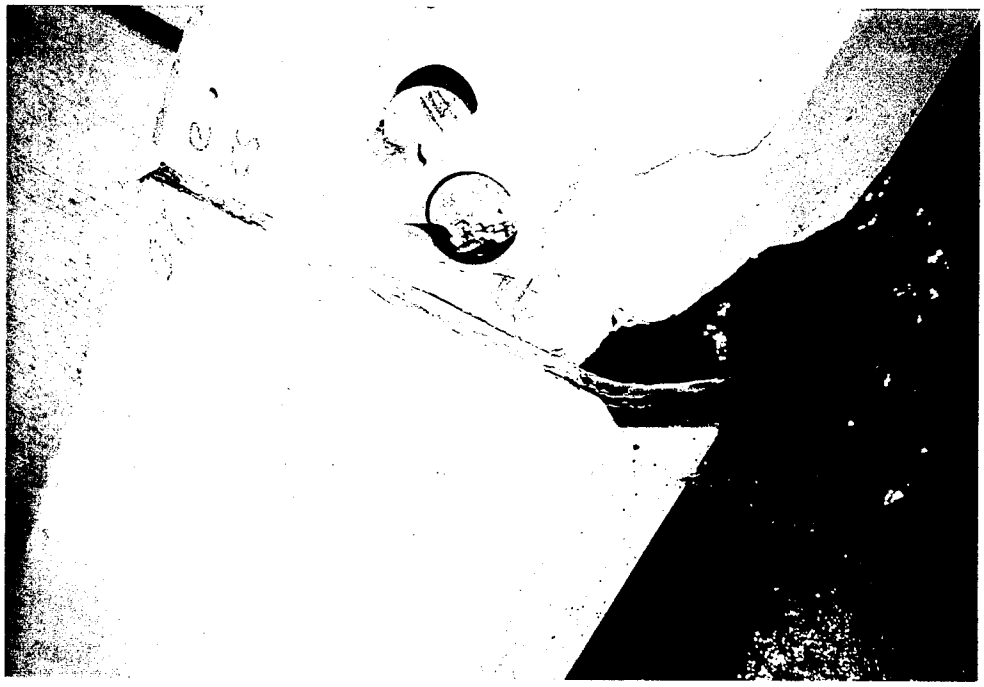


Figure 6. Cracking along lakeside edge at joint 51/52, south seawall monolith S52

Figure 7. Cracking along lakeside edge at joint 52/53 south seawall monolith S52

Figure 8. Cracking along lakeside edge at joint 71/72, south seawall monolith S72

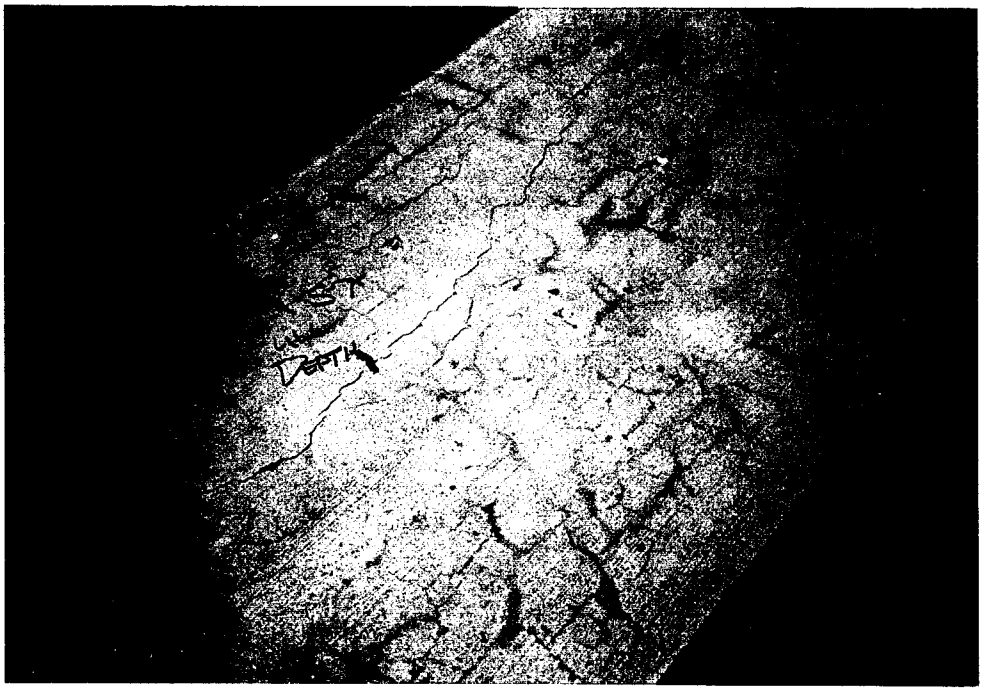


Figure 9. Cracks and stains in top face of south seawall monolith S7

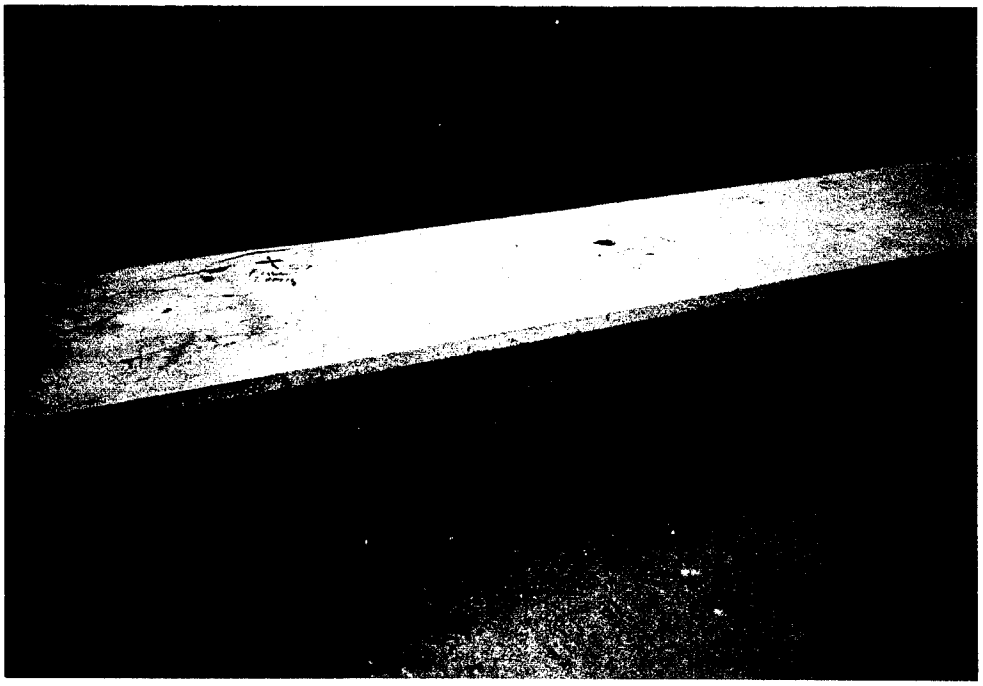


Figure 10. Cracks and stains in landside face of south seawall monolith S7

Figure 11. Cracks and stains in faces of south seawall monolith S17 at joint 17/18

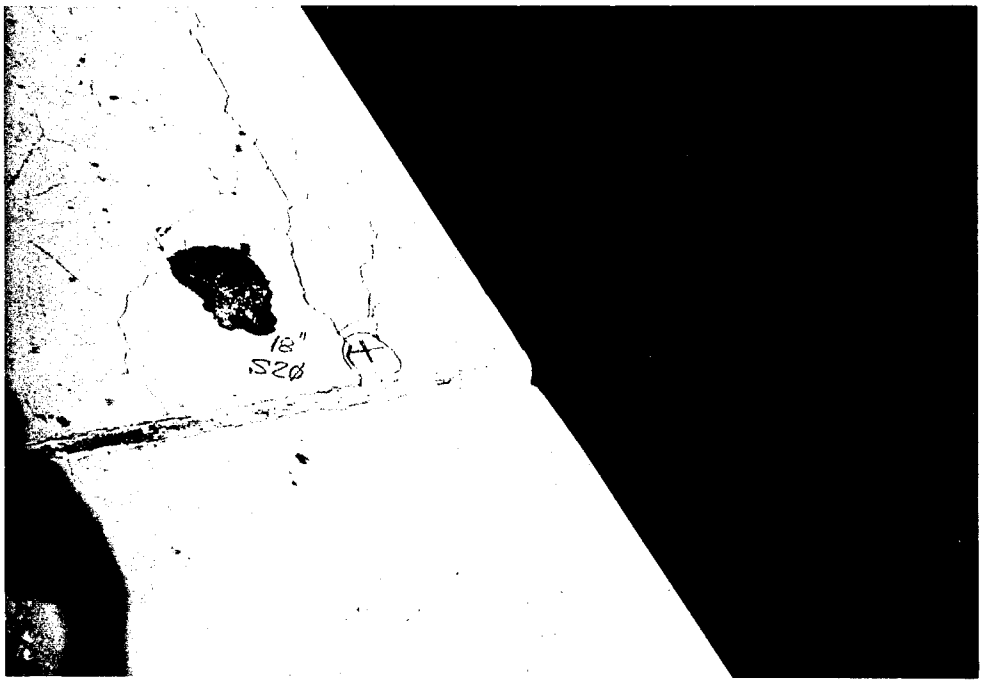


Figure 12. Cracks and stains in south seawall monolith S20 at joint 19/20

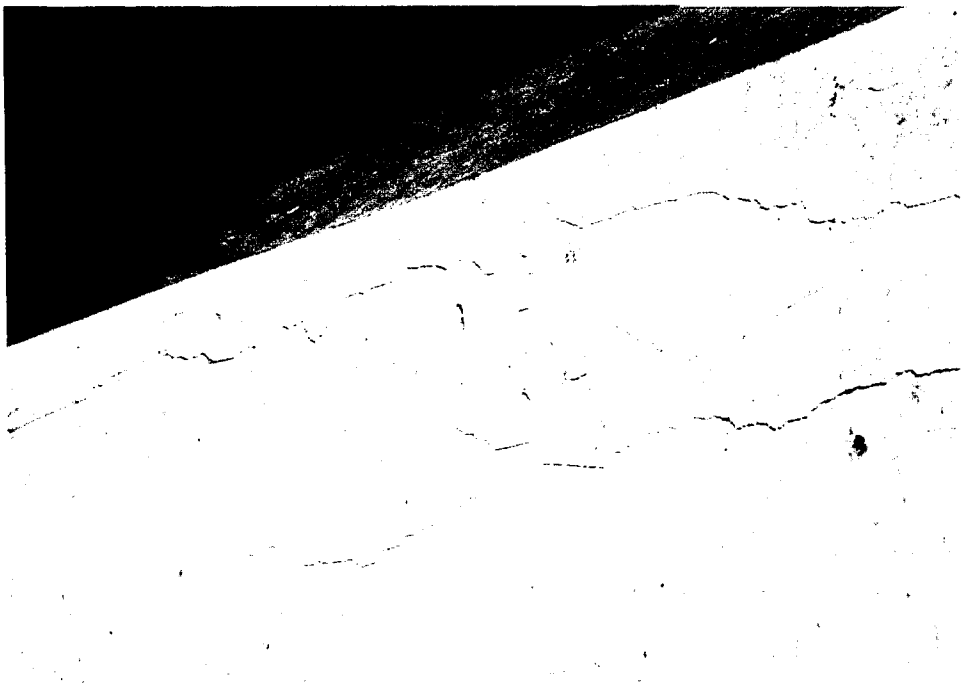


Figure 13. Longitudinal cracks along lakeside edge of south seawall monolith S20

Figure 14. Cracks visible in the surface of boring at joint 19/20, south seawall monolith S20

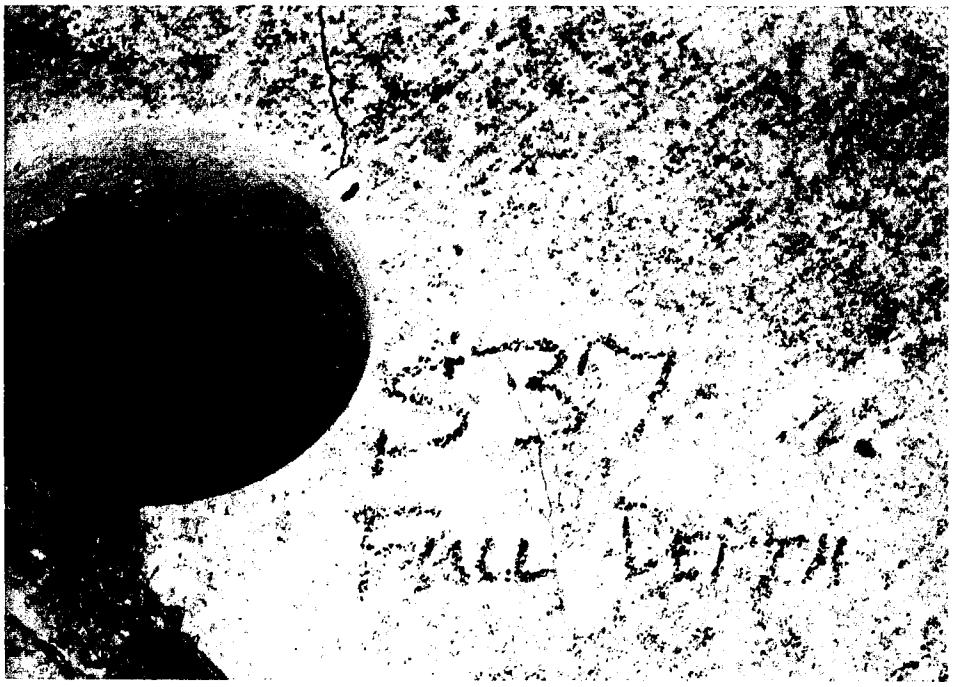


Figure 15. Moisture retained in and around some of the aggregate particles visible in the surface of boring at joint 37/38, south seawall monolith S37

Figure 16. Moisture retained in some of the aggregate particles visible in the surface of boring, south seawall joint 16/17

Figure 17. Monoliths 16 and 17 cast against each other, also moisture retained in and around some aggregate particles of monolith 16

3 Laboratory Tests

Core Tests

A total of 14 specimens (7 from each seawall) were selected from cores and tested in compression in accordance with ASTM C 39 and ASTM C 42. Ultrasonic pulse velocities and densities were also determined for each sample. The results of core tests are presented in Table 5.

Compressive Strength

The compressive strengths of the cores from the north seawall ranged from 31.7 to 58.7 MPa (4,600 to 8,510 psi) with an average strength of 46.0 MPa (6,680 psi). The compressive strengths of the cores from the south seawall ranged from 38.9 to 66.1 MPa (5,650 to 9,590 psi) with an average strength of 52.6 MPa (7,630 psi).

Pulse Velocity

The pulse velocity measurements on cores from the north seawall ranged from 4,182 to 4,803 m/s (13,720 to 15,758 ft/s) with an average velocity of 4,524 m/s (14,841 ft/s). The pulse velocity measurements on the cores from the south seawall ranged from 4,543 to 4,726 m/s (14,906 to 15,506 ft/s) with an average velocity of 4,623 m/s (15,166 ft/s). A correlation between compressive strength and pulse velocity is presented in Figure 18.

Density

The density of the cores from the north seawall ranged from 2.23 to 2.40 Mg/m^3 (139 to 150 lb/ft^3) with an average density of 2.27 Mg/m^3 (142 lb/ft^3). The density of the cores from the south seawall ranged from 2.23 to 2.37 Mg/m^3 (139 to 148 lb/ft^3) with an average density of the south seawall of 2.31 Mg/m^3 (144 lb/ft^3).

Table 5
Test Results for Core Specimens taken from Seawalls

Core Location	Specimen Number	Mass Density Mg/m^3 (lb/ft^3)	Pulse Velocity m/s (ft/s)	Before Capping			After Capping		Unconfined Compressive Strength (ASTM C 42) MPa (psi)
				Length mm (in.)	Diameter mm (in.)	L/D Ratio	Length mm (in.)	L/D Ratio	
N11	1	2.40 (150)	4,182 (13,720)	206 (8.10)	102 (4.00)	2.03	210 (8.28)	2.07	36.6 (5,310)
N21	1	2.26 (141)	4,803 (15,758)	203 (8.00)	102 (4.00)	2.00	206 (8.12)	2.03	50.3 (7,300)
	2	2.29 (143)	4,486 (14,717)	203 (8.00)	102 (4.00)	2.00	208 (8.20)	2.05	52.0 (7,540)
N30	1	2.23 (139)	4,705 (15,436)	206 (8.12)	102 (4.00)	2.03	209 (8.22)	2.06	58.7 (8,510)
N45	1	2.32 (145)	4,673 (15,331)	206 (8.10)	102 (4.00)	2.03	209 (8.21)	2.05	49.0 (7,110)
N56	1	2.24 (140)	4,341 (14,243)	205 (8.08)	102 (4.00)	2.02	208 (8.19)	2.05	31.7 (4,600)
N57	1	2.23 (139)	4,476 (14,684)	204 (8.02)	102 (4.00)	2.01	207 (8.16)	2.04	44.0 (6,380)
Averages for North Seawall		2.27 (142)	4,524 (14,841)						46.0 (6,680)
S8	1	2.23 (139)	4,580 (15,026)	207 (8.13)	102 (4.00)	2.03	209 (8.23)	2.06	53.4 (7,740)
	2	2.24 (140)	4,613 (15,134)	201 (7.93)	102 (4.00)	1.98	207 (8.14)	2.04	49.3 (7,160)
S17B	1	2.26 (141)	4,658 (15,281)	205 (8.08)	102 (4.00)	2.02	208 (8.18)	2.05	54.0 (7,830)
S27	1	2.35 (147)	4,544 (14,907)	203 (8.00)	102 (4.00)	2.00	206 (8.11)	2.03	38.9 (5,650)
S52B	1	2.37 (148)	4,726 (15,506)	206 (8.10)	102 (4.00)	2.03	209 (8.24)	2.06	52.9 (7,680)
S68	1	2.31 (144)	4,694 (15,400)	206 (8.10)	102 (4.00)	2.03	209 (8.22)	2.06	66.1 (9,590)
S72	1	2.34 (146)	4,543 (14,906)	163 (6.40)	102 (4.00)	1.60	168 (6.61)	1.65	53.9 (7,810)
Averages for South Seawall		2.31 (144)	4,623 (15,166)						52.6 (7,630)

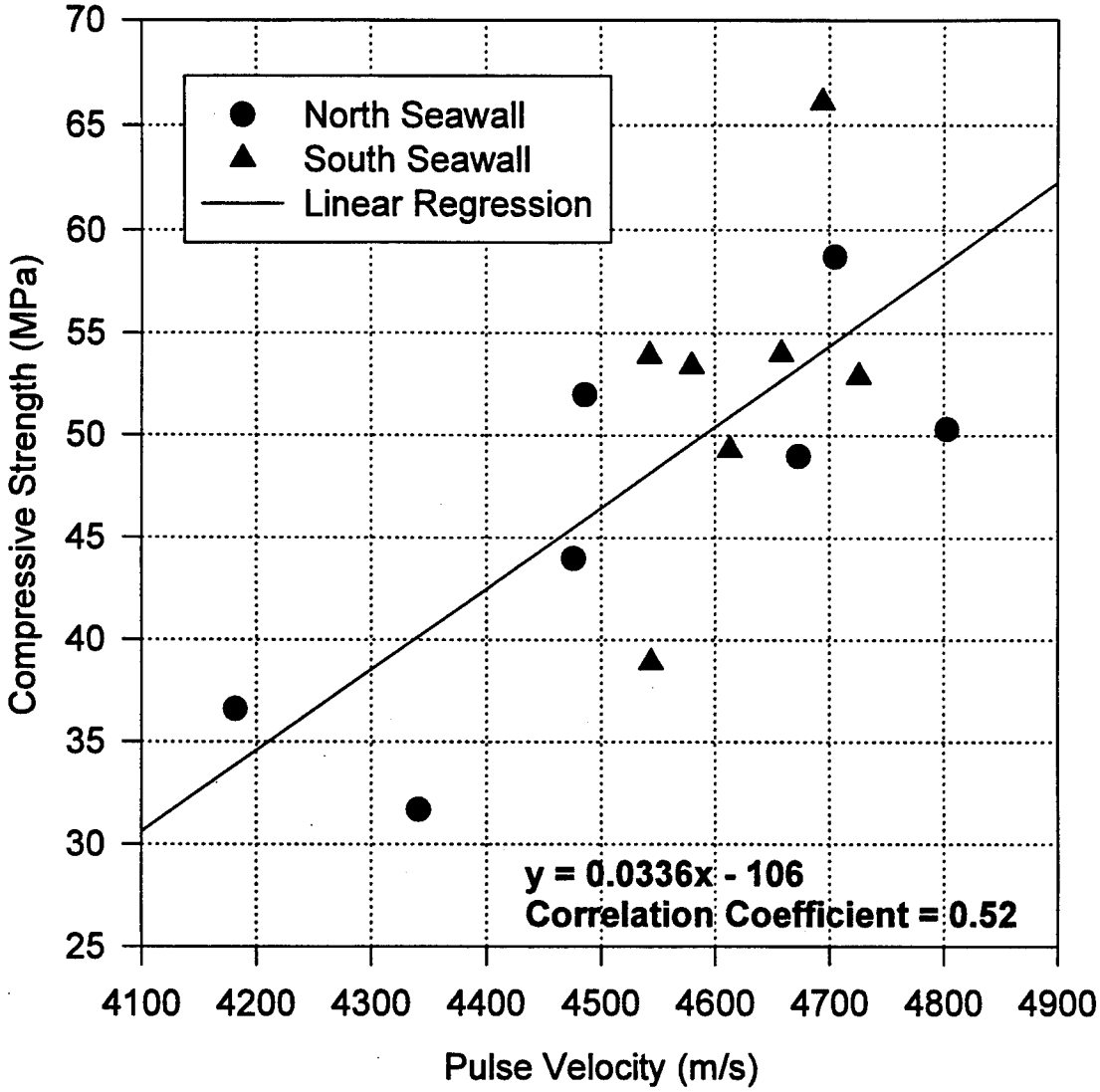


Figure 18. Compressive strength vs pulse velocity for core samples

Petrographic Examination

A total of 27 samples (9 north seawall, 2 old seawall, and 16 south seawall) were evaluated in accordance with ASTM C 856. The air content and the air-void spacing factor of the cement paste were determined in accordance with ASTM C 457 for selected concrete specimens removed from cores. Specific gravities and water absorption values for the coarse aggregate were determined in accordance with ASTM C 127 for selected individual aggregate particles removed from cores. The results of the petrographic examination of cores are detailed in Appendix B.

Cement Paste

The air-void content and parameters of the air-void system in the hardened concrete were determined in accordance with ASTM C 457. The concrete from the north and south seawalls and from old seawall contained some entrained air. The total air content ranged from a high of near six percent to a low of near one percent. Spacing factors showed a range of 0.780 to 0.213 mm (0.0307 to 0.0084 in.). The air-void system should have a spacing factor of 0.2 mm (0.008 in.) or less to provide adequate protection from stresses associated with freezing and thawing of critically saturated concrete.

Examination of concrete in adjacent monoliths indicated that one may be protected while the other may be susceptible to freezing and thawing deterioration. Samples from a core drilled through a joint representing concrete from monoliths S16 and S17 of the south seawall showed the spacing factor for concrete in monolith S16 to be significantly higher than that for monolith S17 (Table B-2, Appendix B). During the visual inspection of the south seawall, the concrete in monolith S16 at joint 16/17 was observed to be significantly more distressed than the concrete in monolith S17. Low pulse velocity readings were recorded in monolith 16 for the concrete near the joint.

Coarse Aggregate

Specific gravities of the coarse aggregate particles ranged from a low of 2.16 to a high of 2.89. The water absorption correlated with specific gravity in that particles with low specific gravities also indicated high absorption. The absorption ranged from less than one percent to more than eleven percent.

Aggregate particles with low specific gravities and high absorption usually are not resistant to freezing and thawing. In many places specific gravities of less than 2.4 are indications of potential problem aggregates. Problems associated with nondurable aggregate in this case would likely appear at edges and corners where the concrete has the highest potential for saturation.

The high absorption exhibited by some of the coarse aggregate particles may account for the popouts observed on concrete surfaces.

The dolomitic limestone showed some reaction rims around aggregate particles indicating some alkali-carbonate rock reaction. This reaction does not appear to be a problem as there was no evidence of joint closure in the structure or possible displacement.

Some alkali-silica reaction was observed in some near surface cracks. The gel in the concrete was limited to partially coating some fractures and appeared to be very limited in extent. From cores taken from old seawall, alkali-silica reaction was much more extensive in core sample N34 and was not evident in core N40 that was intact. The concrete was rubble where alkali-silica reaction was observed. Alkali-silica reaction may be a major deteriorating cause in the concrete of the old seawall.

Reinforcing Steel

Minor corrosion of the reinforcing steel was found in the limited samples taken. The corrosion does not appear to be the cause of distress in the concrete. As the structures age and the concrete along open cracks and adjacent to the reinforcing steel carbonates, corrosion of steel could become a problem causing staining and spalling of the concrete. Based on the results from the visual inspection, there is indication that this may be occurring in south seawall monoliths S7, S16, S17, and S20.

4 Conclusions

The results of the petrographic examination of the concrete identified several mechanisms that may contribute to the deterioration of the concrete. Of those, the lack of resistance to freezing and thawing was concluded to be the major contributor to the observed distress and deterioration in the concrete.

The air-void system in the concrete of some monoliths is inadequate for protecting the concrete from damage due to freezing while critically saturated. An examination of selected specimens indicated the concrete from some monoliths has an air-void spacing factor near the critical limit where the concrete would be considered protected while the concrete from other monoliths has an air-void spacing factor that is well outside the protected range.

Both the concrete from the north and south seawalls were similar in composition. The performance is expected to be similar under similar environmental conditions. Both walls contain some aggregate particles that are susceptible to damage due to freezing and thawing while critically saturated. This may manifest itself in D cracking of the concrete at the joints and edges.

Alkali-aggregate reaction and corrosion were recognized as active chemical reactions in the concrete but are believed to be minor contributors to the deterioration process at this time. Of the two cores obtained from the old seawall, one was intact and free of apparent internal distress where the other was totally deteriorated. Only limited consideration was given to the old concrete and alkali-silica reaction may be a factor in deterioration of that concrete. Overall, the deterioration resulting from alkali-silica reaction is not expected to require remedial action in the future.

During the visual inspection of the seawalls, it was observed that a much higher frequency of the distress exists in the south seawall concrete than in north seawall concrete. An increase in damage has been observed in the south face of other structures that lie in a east-west plane. It is believed that the south face of these structures receives more sunlight in the winter than the north face due to the angle of the sun and, thereby, undergoes more cycles of freezing and thawing. This may account for the increased frequency of damage observed in the south seawall.

Most of the distress and deterioration in the concrete was observed along the top-lakeside edges of seawalls at the joints. The exceptions to this were at four south seawall monoliths (S7, S16, S17, and S20) where the damage was distributed

along the length of the monoliths and at a ladder recess in the north seawall monolith N22 where more extensive cracking was observed in top and landside faces of the concrete.

Corrosion of the reinforcing steel was indicated in the four south seawall monoliths by areas of reddish-brown stains coming from cracking along a longitudinal plane in landside and lakeside faces. Reddish-brown stains were also observed coming from cracks in the concrete at the ladder recess of north seawall monolith N22.

There were numerous areas of localized distress in the form of hairline cracks, staining, and popouts. Small areas of reddish-brown stains were observed coming from random and traverse cracks indicating localized corrosion of the reinforcing steel. Again, most of the distress was observed in the south seawall. It is possible that some areas of localized distress will required remedial action in the future for appearance purposes.

All joint seals showed varying degrees of damage, deterioration, and adhesive and cohesive failures. At a few joints, the seal and filler materials were completely missing. No correlation could be made between the missing joint materials and the occurrence of damage to the concrete as there were several joints where there was no joint material and no evidence of distress or deterioration.

5 Recommendations

North Seawall

There are eight locations in the north seawall where removal and replacement of distressed and deteriorated concrete should be considered (Table 6). All but one location is at a joint. In general, it is recommended that for repairs at a joint the concrete be removed and replaced from the joint back approximately 610 mm (24 in.) and from the top down approximately 380 mm (15 in.). For the repair at the ladder recess in monolith N22, it is recommended that approximately 380 mm (15 in.) of the concrete be removed and replaced from the vertical face between the top and ground level and 300 mm (12 in.) to either side of ladder blockout.

South Seawall

There are forty locations in the south seawall where distressed and deteriorated concrete should be consider for removal and replacement (Table 7). Four locations (monoliths S7, S16, S17, and S20) include removal and replacement of the top 460 mm (18 in.) of the monolith and the other thirty-six locations are for repairs at a joint. In general, it is recommended that for repairs at a joint the concrete be removed and replace from the joint back approximately 610 mm (24 in.) and from the top down approximately 380 mm (15 in.).

Table 6
Recommended Repairs to North Seawall

Monolith	Reference Point	Description of Repair
N10*	Joint 9/10	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N10*	Joint 10/11	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N11*	Joint 10/11	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N11*	Joint 11/12	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N14*	Joint 13/14	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N22*	Joint 21/22	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
N22	Ladder Recess	Remove and replace approximately 380 mm (15 in.) of concrete from vertical face between the top and ground level and 300 mm (12 in.) to either side of ladder blockout
N60*	Joint 59/60	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)

* Low Pulse Velocity Measurement

Table 7
Recommended Repairs to South Seawall (Continued)

Monolith	Reference Point	Description of Repair
S1*	Joint 1/2	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.) and make joint vertical at top
S7*	Entire Monolith	Remove and replace top 460 mm (18 in.) of monolith
S16*	Entire Monolith	Remove and replace top 460 mm (18 in.) of monolith
S17*	Entire Monolith	Remove and replace top 460 mm (18 in.) of monolith
S18*	Joint 18/19	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S20*	Entire Monolith	Remove and replace top 460 mm (18 in.) of monolith
S27	Joint 27/28	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S29	Joint 28/29	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S30*	Joint 29/30	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S31*	Joint 31/32	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S32	Joint 32/33	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S33*	Joint 32/33	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S33	Joint 33/34	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S34	Joint 33/34	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)

* Low Pulse Velocity Measurement

Table 7
Recommended Repairs to South Seawall (Continued)

Monolith	Reference Point	Description of Repair
S37	Joint 37/38	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S38	Joint 37/38	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S39	Joint 38/39	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S39	Joint 39/40	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S40	Joint 39/40	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S40*	Joint 40/41	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S41	Joint 41/42	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S42*	Joint 41/42	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S42	Joint 42/43	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S43	Joint 42/43	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S46	Joint 45/46	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S49*	Joint 48/49	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S52*	Joint 51/52	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S52*	Joint 52/53	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S53*	Joint 52/53	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)

* Low Pulse Velocity Measurement

Table 7
Recommended Repairs to South Seawall (Concluded)

Monolith	Reference Point	Description of Repair
S53	Joint 53/54	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S58*	Joint 57/58	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S59*	Joint 58/59	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S60*	Joint 59/60	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S63*	Joint 62/63	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S63*	Joint 63/64	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S64	Joint 63/64	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S67*	Joint 66/67	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S67*	Joint 67/68	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S72*	Joint 71/72	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)
S72*	Joint 72/73	Remove and replace from joint back approximately 610 mm (24 in.) and from top down 380 mm (15 in.)

* Low Pulse Velocity Measurement

Overall

Additional removal and replacement will be required if sound concrete is not reached within specified repair limits. A minimum 25 mm (1-in.) saw cut should be made along removal boundaries to reduce the occurrence of feather edges during removal. If damage to a reinforcing bar has reduced the effective cross-sectional area by 25 percent or more, additional reinforcement should be added. Exposed concrete surfaces and reinforcing should be sandblasted prior to placement of concrete.

A conventional concrete should be used to make repairs. The concrete should have adequate air content to protect repair against freeze-thaw damage. The coarse aggregate should be tested for resistance to freezing and thawing (ASTM C 666, Procedure A).

Cracking has been a problem in some overlays and large repairs . It is believed that the cracking was the result of thermal and drying volume changes acting upon the highly restrained repair. To reduce the potential for such cracking, positive steps should be specified and followed to minimize temperature differentials and shrinkage. Reduced cracking in lock wall resurfacing has been attributed to lowering cement content, increasing the maximum size coarse aggregate, utilizing lower placing and curing temperatures, and paying close attention to curing (Wickersham 1987).

It is recommended that a surface sealer be applied to monolith tops and to lakeside and landside faces from top of monolith to minimum of 460 mm (18 in.) below. The sealer selected should allow significant water vapor transfer to avoid a critically water saturated condition that would result in damage due to freezing and thawing. Criteria for selection of sealers along with the test results of some 90 commercial surface treatment products can be found in Technical Report REMR-CS-17, Report 2 (Husbands and Causey 1990). Of the products tested only five products met the criteria (one hydrocarbon, two siloxanes, and two silanes). The manufacturer will have to be contacted regarding conditions under which a particular sealer can be applied as the application varies greatly between types of sealers.

It is also recommended that existing seals be removed and new seals installed at all joints.

Additional evaluation of the seawalls may be required as the lakeside faces of seawalls were not accessible due to high lake levels when field evaluation was performed. It is expected that the concrete in the lakeside surfaces has less than or minimal resistance to freezing and thawing damage when critically saturated. Therefore, it may be prudent to apply sealer to the full height of lakeside surfaces. The concrete in the sidewalk portion of the south seawall was not tested. The sidewalk did have minor cracking at the corner of one joint. The repair of this corner would only be necessary for appearance.

Maintenance

Because of the inadequate air-void system within the concrete, there is potential for the deterioration due to freezing and thawing to continue in what is now sound concrete, assuming critical saturation of the concrete. To minimize this potential, it is recommended that the sealer be reapplied periodically. The time interval between applications depends on the product used. For many sealers, the recommended interval is 5 years.

References

American Society of Testing Materials. 1994. 1994 Annual Book of ASTM Standards. Philadelphia, PA.

a. Designation C 39. "Standard test method for compressive strength of cylindrical concrete specimens."

b. Designation C 42. "Standard test method for obtaining and testing drilled cores and sawed beams of concrete."

c. Designation C 127. "Standard test method for specific gravity and absorption of coarse aggregate."

d. Designation C 457. "Standard practice for microscopical determination of air-void content and parameters of the air-void system in hardened concrete."

e. Designation C 597. "Standard test method for pulse velocity through concrete."

f. Designation C 666. "Standard test method for resistance of concrete to rapid freezing and thawing."

g. Designation C 856. "Standard practice for petrographic examination of hardened concrete."

Husbands, T. B. and Causey, F. E. (1990). "Surface treatments to minimize concrete deterioration, laboratory evaluation of surface treatment materials," Technical Report REMR-CS-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Leslie, J. R. and Cheesman, W. J. (1949). " An ultrasonic method of studying deterioration and cracking in concrete structures,: ACI Journal, *Proceedings*, Vol 46, No. 1, pp 17-36

Lewandowski, F. (1994). "Inspection and preliminary evaluation of concrete seawalls at Perry's Victory and International Peace Memorial, Put-in-Bay, (South Bass Island) Ohio," US Army Corps of Engineers District, Buffalo, Buffalo, NY (Unpublished.)

Wickersham, J. (1987.) "Concrete rehabilitation at Lock and Dam No. 20, Mississippi River," The REMR Bulletin, Vol 4, No. 4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Appendix A1
Pulse Velocity Measurements

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N2	0.08 (0.25)	297	1.334 (4.375)	4490 (14731)
	1.52 (5.00)	292	1.334 (4.375)	4567 (14983)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	292	1.334 (4.375)	4567 (14983)
	5.94 (19.50)	315	1.334 (4.375)	4233 (13889)
N3	0.08 (0.25)	289	1.334 (4.375)	4614 (15138)
	1.52 (5.00)	294	1.334 (4.375)	4536 (14881)
	3.05 (10.00)	293	1.334 (4.375)	4551 (14932)
	4.57 (15.00)	289	1.334 (4.375)	4614 (15138)
	6.10 (20.00)	290	1.334 (4.375)	4598 (15086)
N4	0.08 (0.25)	301	1.334 (4.375)	4430 (14535)
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	300	1.334 (4.375)	4445 (14583)
	4.57 (15.00)	287	1.334 (4.375)	4646 (15244)
	5.94 (19.50)	294	1.334 (4.375)	4536 (14881)
N5	0.08 (0.25)	347	1.334 (4.375)	3843 (12608)
	1.52 (5.00)	307	1.334 (4.375)	4344 (14251)
	3.05 (10.00)	302	1.334 (4.375)	4416 (14487)
	4.57 (15.00)	303	1.334 (4.375)	4401 (14439)
	6.02 (19.75)	304	1.334 (4.375)	4387 (14391)
N6	0.08 (0.25)	457	1.334 (4.375)	2918 (9573)*
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	296	1.334 (4.375)	4505 (14780)
	4.57 (15.00)	319	1.334 (4.375)	4180 (13715)
	5.94 (19.50)	299	1.334 (4.375)	4460 (14632)
N7	0.08 (0.25)	650	1.334 (4.375)	2052 (6731)*
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	293	1.334 (4.375)	4551 (14932)
	4.57 (15.00)	294	1.334 (4.375)	4536 (14881)
	6.02 (19.75)	296	1.334 (4.375)	4505 (14780)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N8	0.08 (0.25)	313	1.334 (4.375)	4260 (13978)
	1.52 (5.00)	314	1.334 (4.375)	4247 (13933)
	3.05 (10.00)	292	1.334 (4.375)	4567 (14983)
	4.57 (15.00)	291	1.334 (4.375)	4582 (15034)
	6.10 (20.00)	500	1.334 (4.375)	2667 (8750)*
N9	0.08 (0.25)	600	1.334 (4.375)	2223 (7292)*
	1.52 (5.00)	296	1.334 (4.375)	4505 (14780)
	3.05 (10.00)	302	1.334 (4.375)	4416 (14487)
	4.57 (15.00)	302	1.334 (4.375)	4416 (14487)
	6.10 (20.00)	462	1.334 (4.375)	2886 (9470)*
N10	0.08 (0.25)	delam.	1.334 (4.375)	ERR*
	1.52 (5.00)	300	1.334 (4.375)	4445 (14583)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	296	1.334 (4.375)	4505 (14780)
	6.10 (20.00)	delam.	1.334 (4.375)	ERR*
N11	0.08 (0.25)	delam.	1.334 (4.375)	ERR*
	1.52 (5.00)	290	1.334 (4.375)	4598 (15086)
	3.05 (10.00)	289	1.334 (4.375)	4614 (15138)
	4.57 (15.00)	287	1.334 (4.375)	4646 (15244)
	5.94 (19.50)	delam.	1.334 (4.375)	ERR*
N12	0.08 (0.25)	500	1.334 (4.375)	2667 (8750)*
	1.52 (5.00)	293	1.334 (4.375)	4551 (14932)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	292	1.334 (4.375)	4567 (14983)
	6.10 (20.00)	293	1.334 (4.375)	4551 (14932)
N13	0.08 (0.25)	322	1.334 (4.375)	4141 (13587)
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	299	1.334 (4.375)	4460 (14632)
	4.57 (15.00)	298	1.334 (4.375)	4475 (14681)
	5.94 (19.50)	297	1.334 (4.375)	4490 (14731)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N14	0.08 (0.25)	472	1.334 (4.375)	2825 (9269)*
	1.52 (5.00)	290	1.334 (4.375)	4598 (15086)
	3.05 (10.00)	290	1.334 (4.375)	4598 (15086)
	4.57 (15.00)	311	1.334 (4.375)	4288 (14068)
	6.10 (20.00)	560	1.334 (4.375)	2381 (7813)*
N15	0.08 (0.25)	331	1.334 (4.375)	4029 (13218)
	1.52 (5.00)	305	1.334 (4.375)	4372 (14344)
	3.05 (10.00)	301	1.334 (4.375)	4430 (14535)
	4.57 (15.00)	307	1.334 (4.375)	4344 (14251)
	6.02 (19.75)	302	1.334 (4.375)	4416 (14487)
N16	0.08 (0.25)	309	1.334 (4.375)	4316 (14159)
	1.52 (5.00)	313	1.334 (4.375)	4260 (13978)
	3.05 (10.00)	309	1.334 (4.375)	4316 (14159)
	4.57 (15.00)	334	1.334 (4.375)	3993 (13099)
	6.02 (19.75)	310	1.334 (4.375)	4302 (14113)
N17	0.08 (0.25)	300	1.334 (4.375)	4445 (14583)
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	297	1.334 (4.375)	4490 (14731)
	6.10 (20.00)	290	1.334 (4.375)	4598 (15086)
N18	0.08 (0.25)	670	1.334 (4.375)	1990 (6530)*
	1.52 (5.00)	275	1.334 (4.375)	4849 (15909)
	3.05 (10.00)	290	1.334 (4.375)	4598 (15086)
	4.57 (15.00)	288	1.334 (4.375)	4630 (15191)
	6.10 (20.00)	287	1.334 (4.375)	4646 (15244)
	7.62 (25.00)	285	1.334 (4.375)	4679 (15351)
	9.45 (31.00)	292	1.334 (4.375)	4567 (14983)
	10.67 (35.00)	300	1.334 (4.375)	4445 (14583)
	12.19 (40.00)	300	1.334 (4.375)	4445 (14583)
	14.63 (48.00)	296	1.334 (4.375)	4505 (14780)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N19	0.08 (0.25)	293	1.334 (4.375)	4551 (14932)
	1.52 (5.00)	292	1.334 (4.375)	4567 (14983)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	293	1.334 (4.375)	4551 (14932)
	6.10 (20.00)	296	1.334 (4.375)	4505 (14780)
	7.62 (25.00)	301	1.334 (4.375)	4430 (14535)
	9.14 (30.00)	296	1.334 (4.375)	4505 (14780)
	10.67 (35.00)	301	1.334 (4.375)	4430 (14535)
	12.19 (40.00)	315	1.334 (4.375)	4233 (13889)
	13.72 (45.00)	292	1.334 (4.375)	4567 (14983)
	14.63 (48.00)	405	1.334 (4.375)	3293 (10802)*
N20	0.08 (0.25)	450	1.334 (4.375)	2963 (9722)*
	1.52 (5.00)	287	1.334 (4.375)	4646 (15244)
	3.05 (10.00)	293	1.334 (4.375)	4551 (14932)
	4.57 (15.00)	296	1.334 (4.375)	4505 (14780)
	6.10 (20.00)	294	1.334 (4.375)	4536 (14881)
	7.62 (25.00)	304	1.334 (4.375)	4387 (14391)
	9.14 (30.00)	293	1.334 (4.375)	4551 (14932)
	10.67 (35.00)	297	1.334 (4.375)	4490 (14731)
	12.19 (40.00)	295	1.334 (4.375)	4520 (14831)
	13.72 (45.00)	298	1.334 (4.375)	4475 (14681)
	14.63 (48.00)	301	1.334 (4.375)	4430 (14535)
N21	0.08 (0.25)	587	1.334 (4.375)	2272 (7453)*
	1.52 (5.00)	297	1.334 (4.375)	4490 (14731)
	3.05 (10.00)	300	1.334 (4.375)	4445 (14583)
	4.57 (15.00)	307	1.334 (4.375)	4344 (14251)
	6.10 (20.00)	304	1.334 (4.375)	4387 (14391)
	7.62 (25.00)	292	1.334 (4.375)	4567 (14983)
	9.14 (30.00)	292	1.334 (4.375)	4567 (14983)
	10.67 (35.00)	301	1.334 (4.375)	4430 (14535)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N21	12.19 (40.00)	291	1.334 (4.375)	4582 (15034)
	13.72 (45.00)	295	1.334 (4.375)	4520 (14831)
	14.55 (47.75)	288	1.334 (4.375)	4630 (15191)
N22	0.08 (0.25)	delam.	1.334 (4.375)	ERR*
	1.52 (5.00)	600	1.334 (4.375)	2223 (7292)*
	3.05 (10.00)	290	1.334 (4.375)	4598 (15086)
	4.57 (15.00)	287	1.334 (4.375)	4646 (15244)
	6.10 (20.00)	290	1.334 (4.375)	4598 (15086)
	7.62 (25.00)	291	1.334 (4.375)	4582 (15034)
	9.14 (30.00)	291	1.334 (4.375)	4582 (15034)
	10.67 (35.00)	315	1.334 (4.375)	4233 (13889)
	12.19 (40.00)	325	1.334 (4.375)	4103 (13462)
	13.72 (45.00)	291	1.334 (4.375)	4582 (15034)
	14.63 (48.00)	286	1.334 (4.375)	4663 (15297)
N23	0.08 (0.25)	293	1.334 (4.375)	4551 (14932)
	1.52 (5.00)	300	1.334 (4.375)	4445 (14583)
	3.05 (10.00)	302	1.334 (4.375)	4416 (14487)
	4.57 (15.00)	294	1.334 (4.375)	4536 (14881)
	6.10 (20.00)	297	1.334 (4.375)	4490 (14731)
	7.62 (25.00)	298	1.334 (4.375)	4475 (14681)
	9.14 (30.00)	295	1.334 (4.375)	4520 (14831)
	10.67 (35.00)	287	1.334 (4.375)	4646 (15244)
	12.19 (40.00)	290	1.334 (4.375)	4598 (15086)
	13.72 (45.00)	295	1.334 (4.375)	4520 (14831)
	14.55 (47.75)	390	1.334 (4.375)	3419 (11218)*
N24	0.08 (0.25)	293	1.334 (4.375)	4551 (14932)
	1.52 (5.00)	299	1.334 (4.375)	4460 (14632)
	3.05 (10.00)	302	1.334 (4.375)	4416 (14487)
	4.57 (15.00)	349	1.334 (4.375)	3821 (12536)
	6.10 (20.00)	306	1.334 (4.375)	4358 (14297)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N24	7.62 (25.00)	504	1.334 (4.375)	2646 (8681)*
	9.14 (30.00)	304	1.334 (4.375)	4387 (14391)
	10.67 (35.00)	315	1.334 (4.375)	4233 (13889)
	12.19 (40.00)	300	1.334 (4.375)	4445 (14583)
	13.72 (45.00)	298	1.334 (4.375)	4475 (14681)
	14.63 (48.00)	287	1.334 (4.375)	4646 (15244)
N25	0.08 (0.25)	279	1.334 (4.375)	4780 (15681)
	1.52 (5.00)	287	1.334 (4.375)	4646 (15244)
	3.05 (10.00)	305	1.334 (4.375)	4372 (14344)
	4.57 (15.00)	297	1.334 (4.375)	4490 (14731)
	6.10 (20.00)	298	1.334 (4.375)	4475 (14681)
	7.62 (25.00)	296	1.334 (4.375)	4505 (14780)
	9.14 (30.00)	305	1.334 (4.375)	4372 (14344)
	10.67 (35.00)	291	1.334 (4.375)	4582 (15034)
	12.19 (40.00)	295	1.334 (4.375)	4520 (14831)
	13.72 (45.00)	306	1.334 (4.375)	4358 (14297)
	14.94 (49.00)	296	1.334 (4.375)	4505 (14780)
N26	0.08 (0.25)	310	1.334 (4.375)	4302 (14113)
	1.52 (5.00)	301	1.334 (4.375)	4430 (14535)
	3.05 (10.00)	301	1.334 (4.375)	4430 (14535)
	4.57 (15.00)	303	1.334 (4.375)	4401 (14439)
	6.10 (20.00)	304	1.334 (4.375)	4387 (14391)
	7.62 (25.00)	303	1.334 (4.375)	4401 (14439)
	9.14 (30.00)	305	1.334 (4.375)	4372 (14344)
	10.67 (35.00)	309	1.334 (4.375)	4316 (14159)
	12.19 (40.00)	307	1.334 (4.375)	4344 (14251)
	13.72 (45.00)	305	1.334 (4.375)	4372 (14344)
	14.63 (48.00)	305	1.334 (4.375)	4372 (14344)
N27	0.08 (0.25)	400	1.334 (4.375)	3334 (10938)*
	1.52 (5.00)	302	1.334 (4.375)	4416 (14487)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N27	3.05 (10.00)	300	1.334 (4.375)	4445 (14583)
	4.57 (15.00)	320	1.334 (4.375)	4167 (13672)
	6.10 (20.00)	306	1.334 (4.375)	4358 (14297)
	7.62 (25.00)	305	1.334 (4.375)	4372 (14344)
	9.14 (30.00)	307	1.334 (4.375)	4344 (14251)
	10.67 (35.00)	304	1.334 (4.375)	4387 (14391)
	12.19 (40.00)	298	1.334 (4.375)	4475 (14681)
	13.72 (45.00)	296	1.334 (4.375)	4505 (14780)
	14.63 (48.00)	294	1.334 (4.375)	4536 (14881)
N28	0.08 (0.25)	302	1.334 (4.375)	4416 (14487)
	1.52 (5.00)	308	1.334 (4.375)	4330 (14205)
	3.05 (10.00)	310	1.334 (4.375)	4302 (14113)
	4.57 (15.00)	307	1.334 (4.375)	4344 (14251)
	6.10 (20.00)	308	1.334 (4.375)	4330 (14205)
	7.62 (25.00)	293	1.334 (4.375)	4551 (14932)
	9.14 (30.00)	301	1.334 (4.375)	4430 (14535)
	10.67 (35.00)	301	1.334 (4.375)	4430 (14535)
	12.19 (40.00)	303	1.334 (4.375)	4401 (14439)
	13.72 (45.00)	301	1.334 (4.375)	4430 (14535)
	14.63 (48.00)	297	1.334 (4.375)	4490 (14731)
N29	0.08 (0.25)	600	1.334 (4.375)	2223 (7292)*
	1.52 (5.00)	293	1.334 (4.375)	4551 (14932)
	3.05 (10.00)	296	1.334 (4.375)	4505 (14780)
	4.57 (15.00)	301	1.334 (4.375)	4430 (14535)
	6.10 (20.00)	306	1.334 (4.375)	4358 (14297)
	7.62 (25.00)	305	1.334 (4.375)	4372 (14344)
	9.14 (30.00)	303	1.334 (4.375)	4401 (14439)
	10.67 (35.00)	334	1.334 (4.375)	3993 (13099)
	12.19 (40.00)	339	1.334 (4.375)	3934 (12906)
	13.72 (45.00)	334	1.334 (4.375)	3993 (13099)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N29	14.63 (48.00)	291	1.334 (4.375)	4582 (15034)
N30	0.08 (0.25)	292	1.334 (4.375)	4567 (14983)
	1.52 (5.00)	303	1.334 (4.375)	4401 (14439)
	3.05 (10.00)	303	1.334 (4.375)	4401 (14439)
	4.57 (15.00)	303	1.334 (4.375)	4401 (14439)
	6.10 (20.00)	289	1.334 (4.375)	4614 (15138)
	7.62 (25.00)	292	1.334 (4.375)	4567 (14983)
	9.14 (30.00)	304	1.334 (4.375)	4387 (14391)
	10.67 (35.00)	298	1.334 (4.375)	4475 (14681)
	12.19 (40.00)	302	1.334 (4.375)	4416 (14487)
	13.72 (45.00)	299	1.334 (4.375)	4460 (14632)
	14.63 (48.00)	295	1.334 (4.375)	4520 (14831)
N31	0.08 (0.25)	410	1.334 (4.375)	3252 (10671)*
	1.52 (5.00)	291	1.334 (4.375)	4582 (15034)
	3.05 (10.00)	299	1.334 (4.375)	4460 (14632)
	4.57 (15.00)	297	1.334 (4.375)	4490 (14731)
	6.10 (20.00)	289	1.334 (4.375)	4614 (15138)
	7.62 (25.00)	292	1.334 (4.375)	4567 (14983)
	9.14 (30.00)	350	1.334 (4.375)	3810 (12500)
	10.67 (35.00)	293	1.334 (4.375)	4551 (14932)
	12.19 (40.00)	297	1.334 (4.375)	4490 (14731)
	13.72 (45.00)	295	1.334 (4.375)	4520 (14831)
	14.63 (48.00)	700	1.334 (4.375)	1905 (6250)*
N32	0.08 (0.25)	295	1.334 (4.375)	4520 (14831)
	1.52 (5.00)	299	1.334 (4.375)	4460 (14632)
	3.05 (10.00)	296	1.334 (4.375)	4505 (14780)
	4.57 (15.00)	299	1.334 (4.375)	4460 (14632)
	6.10 (20.00)	300	1.334 (4.375)	4445 (14583)
	7.62 (25.00)	303	1.334 (4.375)	4401 (14439)
	9.14 (30.00)	305	1.334 (4.375)	4372 (14344)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N32	10.67 (35.00)	330	1.334 (4.375)	4041 (13258)
	12.19 (40.00)	307	1.334 (4.375)	4344 (14251)
	13.72 (45.00)	302	1.334 (4.375)	4416 (14487)
	14.63 (48.00)	306	1.334 (4.375)	4358 (14297)
N33	0.08 (0.25)	287	1.334 (4.375)	4646 (15244)
	1.52 (5.00)	290	1.334 (4.375)	4598 (15086)
	3.05 (10.00)	290	1.334 (4.375)	4598 (15086)
	4.57 (15.00)	333	1.334 (4.375)	4005 (13138)
	6.10 (20.00)	583	1.334 (4.375)	2287 (7504)*
	7.62 (25.00)	293	1.334 (4.375)	4551 (14932)
	9.14 (30.00)	303	1.334 (4.375)	4401 (14439)
	10.67 (35.00)	297	1.334 (4.375)	4490 (14731)
	12.19 (40.00)	290	1.334 (4.375)	4598 (15086)
	13.72 (45.00)	293	1.334 (4.375)	4551 (14932)
	14.63 (48.00)	310	1.334 (4.375)	4302 (14113)
N34	0.08 (0.25)	296	1.334 (4.375)	4505 (14780)
	1.52 (5.00)	298	1.334 (4.375)	4475 (14681)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	291	1.334 (4.375)	4582 (15034)
	6.10 (20.00)	288	1.334 (4.375)	4630 (15191)
	7.62 (25.00)	299	1.334 (4.375)	4460 (14632)
	9.14 (30.00)	293	1.334 (4.375)	4551 (14932)
	10.67 (35.00)	297	1.334 (4.375)	4490 (14731)
	12.19 (40.00)	298	1.334 (4.375)	4475 (14681)
	13.72 (45.00)	293	1.334 (4.375)	4551 (14932)
	14.86 (48.75)	292	1.334 (4.375)	4567 (14983)
N35	0.08 (0.25)	292	1.334 (4.375)	4567 (14983)
	1.52 (5.00)	288	1.334 (4.375)	4630 (15191)
	3.05 (10.00)	285	1.334 (4.375)	4679 (15351)
	4.57 (15.00)	288	1.334 (4.375)	4630 (15191)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N35	6.10 (20.00)	295	1.334 (4.375)	4520 (14831)
	7.62 (25.00)	297	1.334 (4.375)	4490 (14731)
	9.14 (30.00)	300	1.334 (4.375)	4445 (14583)
	10.67 (35.00)	295	1.334 (4.375)	4520 (14831)
	12.19 (40.00)	289	1.334 (4.375)	4614 (15138)
	13.72 (45.00)	290	1.334 (4.375)	4598 (15086)
	14.63 (48.00)	296	1.334 (4.375)	4505 (14780)
N36	0.08 (0.25)	293	1.334 (4.375)	4551 (14932)
	1.52 (5.00)	291	1.334 (4.375)	4582 (15034)
	3.05 (10.00)	291	1.334 (4.375)	4582 (15034)
	4.57 (15.00)	286	1.334 (4.375)	4663 (15297)
	6.10 (20.00)	285	1.334 (4.375)	4679 (15351)
	7.62 (25.00)	282	1.334 (4.375)	4729 (15514)
	9.14 (30.00)	287	1.334 (4.375)	4646 (15244)
	10.67 (35.00)	292	1.334 (4.375)	4567 (14983)
	12.19 (40.00)	293	1.334 (4.375)	4551 (14932)
	13.72 (45.00)	297	1.334 (4.375)	4490 (14731)
	14.78 (48.50)	289	1.334 (4.375)	4614 (15138)
N37	0.08 (0.25)	305	1.334 (4.375)	4372 (14344)
	1.52 (5.00)	302	1.334 (4.375)	4416 (14487)
	3.05 (10.00)	308	1.334 (4.375)	4330 (14205)
	4.57 (15.00)	302	1.334 (4.375)	4416 (14487)
	6.10 (20.00)	302	1.334 (4.375)	4416 (14487)
	7.62 (25.00)	301	1.334 (4.375)	4430 (14535)
	9.14 (30.00)	310	1.334 (4.375)	4302 (14113)
	10.67 (35.00)	310	1.334 (4.375)	4302 (14113)
	12.19 (40.00)	303	1.334 (4.375)	4401 (14439)
	13.72 (45.00)	304	1.334 (4.375)	4387 (14391)
	14.63 (48.00)	296	1.334 (4.375)	4505 (14780)
N38	0.08 (0.25)	525	1.334 (4.375)	2540 (8333)*

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N38	1.52 (5.00)	291	1.334 (4.375)	4582 (15034)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	298	1.334 (4.375)	4475 (14681)
	6.10 (20.00)	293	1.334 (4.375)	4551 (14932)
	7.62 (25.00)	296	1.334 (4.375)	4505 (14780)
	9.14 (30.00)	295	1.334 (4.375)	4520 (14831)
	10.67 (35.00)	301	1.334 (4.375)	4430 (14535)
	12.19 (40.00)	301	1.334 (4.375)	4430 (14535)
	13.72 (45.00)	296	1.334 (4.375)	4505 (14780)
	14.63 (48.00)	302	1.334 (4.375)	4416 (14487)
N39	0.08 (0.25)	307	1.334 (4.375)	4344 (14251)
	1.52 (5.00)	301	1.334 (4.375)	4430 (14535)
	3.05 (10.00)	307	1.334 (4.375)	4344 (14251)
	4.57 (15.00)	301	1.334 (4.375)	4430 (14535)
	6.10 (20.00)	292	1.334 (4.375)	4567 (14983)
	7.62 (25.00)	294	1.334 (4.375)	4536 (14881)
	9.14 (30.00)	297	1.334 (4.375)	4490 (14731)
	10.67 (35.00)	288	1.334 (4.375)	4630 (15191)
	12.19 (40.00)	289	1.334 (4.375)	4614 (15138)
	13.72 (45.00)	289	1.334 (4.375)	4614 (15138)
	14.63 (48.00)	297	1.334 (4.375)	4490 (14731)
N40	0.08 (0.25)	290	1.334 (4.375)	4598 (15086)
	1.52 (5.00)	300	1.334 (4.375)	4445 (14583)
	3.05 (10.00)	298	1.334 (4.375)	4475 (14681)
	4.57 (15.00)	300	1.334 (4.375)	4445 (14583)
	6.10 (20.00)	300	1.334 (4.375)	4445 (14583)
	7.62 (25.00)	297	1.334 (4.375)	4490 (14731)
	9.14 (30.00)	294	1.334 (4.375)	4536 (14881)
	10.67 (35.00)	300	1.334 (4.375)	4445 (14583)
	12.19 (40.00)	308	1.334 (4.375)	4330 (14205)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N40	13.72 (45.00)	307	1.334 (4.375)	4344 (14251)
	14.78 (48.50)	297	1.334 (4.375)	4490 (14731)
N41	0.08 (0.25)	287	1.334 (4.375)	4646 (15244)
	1.52 (5.00)	292	1.334 (4.375)	4567 (14983)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	292	1.334 (4.375)	4567 (14983)
	6.10 (20.00)	297	1.334 (4.375)	4490 (14731)
	7.62 (25.00)	300	1.334 (4.375)	4445 (14583)
	9.14 (30.00)	364	1.334 (4.375)	3663 (12019)
	10.67 (35.00)	299	1.334 (4.375)	4460 (14632)
	12.19 (40.00)	297	1.334 (4.375)	4490 (14731)
	13.72 (45.00)	297	1.334 (4.375)	4490 (14731)
	15.09 (49.50)	292	1.334 (4.375)	4567 (14983)
N42	0.08 (0.25)	284	1.334 (4.375)	4695 (15405)
	1.52 (5.00)	287	1.334 (4.375)	4646 (15244)
	3.05 (10.00)	292	1.334 (4.375)	4567 (14983)
	4.57 (15.00)	299	1.334 (4.375)	4460 (14632)
N43	0.08 (0.25)	297	1.334 (4.375)	4490 (14731)
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	291	1.334 (4.375)	4582 (15034)
	4.57 (15.00)	296	1.334 (4.375)	4505 (14780)
N44	0.08 (0.25)	306	1.334 (4.375)	4358 (14297)
	1.52 (5.00)	294	1.334 (4.375)	4536 (14881)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	320	1.334 (4.375)	4167 (13672)
	6.10 (20.00)	300	1.334 (4.375)	4445 (14583)
	7.16 (23.50)	303	1.334 (4.375)	4401 (14439)
N45	0.08 (0.25)	293	1.334 (4.375)	4551 (14932)
	1.52 (5.00)	293	1.334 (4.375)	4551 (14932)
	3.05 (10.00)	296	1.334 (4.375)	4505 (14780)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N45	5.18 (17.00)	293	1.334 (4.375)	4551 (14932)
	5.79 (19.00)	297	1.334 (4.375)	4490 (14731)
N46	0.08 (0.25)	299	1.334 (4.375)	4460 (14632)
	1.52 (5.00)	295	1.334 (4.375)	4520 (14831)
	3.05 (10.00)	294	1.334 (4.375)	4536 (14881)
	4.57 (15.00)	295	1.334 (4.375)	4520 (14831)
	5.79 (19.00)	310	1.334 (4.375)	4302 (14113)
N47	0.08 (0.25)	296	1.334 (4.375)	4505 (14780)
	1.52 (5.00)	296	1.334 (4.375)	4505 (14780)
	3.05 (10.00)	297	1.334 (4.375)	4490 (14731)
	4.57 (15.00)	304	1.334 (4.375)	4387 (14391)
	5.79 (19.00)	304	1.334 (4.375)	4387 (14391)
N48	0.08 (0.25)	317	1.334 (4.375)	4207 (13801)
	1.52 (5.00)	309	1.334 (4.375)	4316 (14159)
	3.05 (10.00)	309	1.334 (4.375)	4316 (14159)
	4.57 (15.00)	315	1.334 (4.375)	4233 (13889)
	6.10 (20.00)	313	1.334 (4.375)	4260 (13978)
N49	0.08 (0.25)	292	1.334 (4.375)	4567 (14983)
	1.52 (5.00)	294	1.334 (4.375)	4536 (14881)
	3.05 (10.00)	295	1.334 (4.375)	4520 (14831)
	4.57 (15.00)	291	1.334 (4.375)	4582 (15034)
	5.64 (18.50)	294	1.334 (4.375)	4536 (14881)
N50	0.08 (0.25)	302	1.334 (4.375)	4416 (14487)
	1.52 (5.00)	300	1.334 (4.375)	4445 (14583)
	3.05 (10.00)	301	1.334 (4.375)	4430 (14535)
	4.57 (15.00)	295	1.334 (4.375)	4520 (14831)
	5.64 (18.50)	302	1.334 (4.375)	4416 (14487)
N51	0.08 (0.25)	296	1.334 (4.375)	4505 (14780)
	1.52 (5.00)	299	1.334 (4.375)	4460 (14632)
	3.05 (10.00)	296	1.334 (4.375)	4505 (14780)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N51	4.57 (15.00)	295	1.334 (4.375)	4520 (14831)
	5.72 (18.75)	295	1.334 (4.375)	4520 (14831)
N52	0.08 (0.25)	307	1.334 (4.375)	4344 (14251)
	1.52 (5.00)	303	1.334 (4.375)	4401 (14439)
	3.05 (10.00)	301	1.334 (4.375)	4430 (14535)
	4.57 (15.00)	300	1.334 (4.375)	4445 (14583)
	5.79 (19.00)	297	1.334 (4.375)	4490 (14731)
N53	0.08 (0.25)	297	1.334 (4.375)	4490 (14731)
	1.52 (5.00)	293	1.334 (4.375)	4551 (14932)
	3.05 (10.00)	310	1.334 (4.375)	4302 (14113)
	4.57 (15.00)	295	1.334 (4.375)	4520 (14831)
	5.79 (19.00)	293	1.334 (4.375)	4551 (14932)
N54	0.08 (0.25)	306	1.334 (4.375)	4358 (14297)
	1.52 (5.00)	307	1.334 (4.375)	4344 (14251)
	3.05 (10.00)	308	1.334 (4.375)	4330 (14205)
	4.57 (15.00)	305	1.334 (4.375)	4372 (14344)
	5.64 (18.50)	296	1.334 (4.375)	4505 (14780)
N55	0.08 (0.25)	296	1.334 (4.375)	4505 (14780)
	1.52 (5.00)	296	1.334 (4.375)	4505 (14780)
	3.05 (10.00)	301	1.334 (4.375)	4430 (14535)
	4.57 (15.00)	294	1.334 (4.375)	4536 (14881)
	5.18 (17.00)	294	1.334 (4.375)	4536 (14881)
N56	0.08 (0.25)	307	1.334 (4.375)	4344 (14251)
	1.52 (5.00)	300	1.334 (4.375)	4445 (14583)
	3.05 (10.00)	306	1.334 (4.375)	4358 (14297)
	4.57 (15.00)	307	1.334 (4.375)	4344 (14251)
	4.88 (16.00)	304	1.334 (4.375)	4387 (14391)
N57	0.08 (0.25)	315	1.334 (4.375)	4233 (13889)
	1.52 (5.00)	294	1.334 (4.375)	4536 (14881)
	3.05 (10.00)	294	1.334 (4.375)	4536 (14881)

*Low Measurement

Table A-1
Pulse Velocity Measurements from North Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from East End of Monolith m (ft)			
N57	4.57 (15.00)	302	1.334 (4.375)	4416 (14487)
	6.10 (20.00)	300	1.334 (4.375)	4445 (14583)
	6.40 (21.00)	299	1.334 (4.375)	4460 (14632)
N58	0.08 (0.25)	305	1.334 (4.375)	4372 (14344)
	1.52 (5.00)	290	1.334 (4.375)	4598 (15086)
	3.05 (10.00)	352	1.334 (4.375)	3788 (12429)
	4.57 (15.00)	295	1.334 (4.375)	4520 (14831)
	6.10 (20.00)	292	1.334 (4.375)	4567 (14983)
	6.55 (21.50)	299	1.334 (4.375)	4460 (14632)
N59	0.08 (0.25)	315	1.334 (4.375)	4233 (13889)
	1.52 (5.00)	288	1.334 (4.375)	4630 (15191)
	3.05 (10.00)	288	1.334 (4.375)	4630 (15191)
	4.57 (15.00)	298	1.334 (4.375)	4475 (14681)
	6.10 (20.00)	660	1.334 (4.375)	2020 (6629)*
N60	0.08 (0.25)	spalled	1.334 (4.375)	ERR*
	1.52 (5.00)	spalled	1.334 (4.375)	ERR*
	3.05 (10.00)	299	1.334 (4.375)	4460 (14632)
	4.57 (15.00)	302	1.334 (4.375)	4416 (14487)
	6.10 (20.00)	292	1.334 (4.375)	4567 (14983)
	7.62 (25.00)	291	1.334 (4.375)	4582 (15034)

*Low Measurement

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S1	0.08 (0.25)	142	0.622 (2.040)	4382 (14378)
	1.52 (5.00)	143	0.622 (2.040)	4352 (14278)
	3.05 (10.00)	144	0.622 (2.040)	4322 (14178)
	4.57 (15.00)	142	0.622 (2.040)	4382 (14378)
	6.02 (19.75)	326	0.622 (2.040)	1909 (6263)*[1]
S2	0.08 (0.25)	167	0.622 (2.040)	3726 (12226)
	1.52 (5.00)	168	0.622 (2.040)	3704 (12153)
	3.05 (10.00)	162	0.622 (2.040)	3841 (12603)
	4.57 (15.00)	158	0.622 (2.040)	3939 (12922)
	6.10 (20.00)	163	0.622 (2.040)	3818 (12526)
S3	0.08 (0.25)	156	0.622 (2.040)	3989 (13088)
	1.52 (5.00)	145	0.622 (2.040)	4292 (14081)
	3.05 (10.00)	140	0.622 (2.040)	4445 (14584)
	4.57 (15.00)	150	0.622 (2.040)	4149 (13611)
	6.10 (20.00)	162	0.622 (2.040)	3841 (12603)
S4	0.08 (0.25)	150	0.622 (2.040)	4149 (13611)
	1.52 (5.00)	149	0.622 (2.040)	4177 (13703)
	3.05 (10.00)	150	0.622 (2.040)	4149 (13611)
	4.57 (15.00)	147	0.622 (2.040)	4233 (13889)
	6.32 (20.75)	150	0.622 (2.040)	4149 (13611)
S5	0.08 (0.25)	152	0.622 (2.040)	4094 (13432)
	1.52 (5.00)	147	0.622 (2.040)	4233 (13889)
	3.05 (10.00)	148	0.622 (2.040)	4205 (13795)
	4.57 (15.00)	149	0.622 (2.040)	4177 (13703)
	5.79 (19.00)	140	0.622 (2.040)	4445 (14584)
S6	0.08 (0.25)	140	0.622 (2.040)	4445 (14584)
	1.52 (5.00)	146	0.622 (2.040)	4262 (13984)
	3.05 (10.00)	146	0.622 (2.040)	4262 (13984)
	4.57 (15.00)	147	0.622 (2.040)	4233 (13889)
	6.10 (20.00)	148	0.622 (2.040)	4205 (13795)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S6	6.32 (20.75)	144	0.622 (2.040)	4322 (14178)
S7	0.08 (0.25)	188	0.622 (2.040)	3310 (10860)*[1]
	1.52 (5.00)	189	0.622 (2.040)	3293 (10803)*[1]
	3.05 (10.00)	151	0.622 (2.040)	4121 (13521)[3]
	4.57 (15.00)	143	0.622 (2.040)	4352 (14278)[3]
	6.10 (20.00)	163	0.622 (2.040)	3818 (12526)[3]
S8	0.08 (0.25)	150	0.622 (2.040)	4149 (13611)
	1.52 (5.00)	145	0.622 (2.040)	4292 (14081)
	3.05 (10.00)	144	0.622 (2.040)	4322 (14178)
	4.57 (15.00)	149	0.622 (2.040)	4177 (13703)
	6.10 (20.00)	148	0.622 (2.040)	4205 (13795)
	6.63 (21.75)	148	0.622 (2.040)	4205 (13795)
S9	0.08 (0.25)	145	0.622 (2.040)	4292 (14081)
	1.52 (5.00)	144	0.622 (2.040)	4322 (14178)
	3.05 (10.00)	142	0.622 (2.040)	4382 (14378)
	4.57 (15.00)	141	0.622 (2.040)	4414 (14480)
	6.10 (20.00)	141	0.622 (2.040)	4414 (14480)
	6.40 (21.00)	138	0.622 (2.040)	4509 (14795)
S10	0.08 (0.25)	139	0.622 (2.040)	4477 (14688)
	1.52 (5.00)	141	0.622 (2.040)	4414 (14480)
	3.05 (10.00)	152	0.622 (2.040)	4094 (13432)
	3.96 (13.00)	144	0.622 (2.040)	4322 (14178)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	180	0.800 (2.625)	4445 (14583)
S11	0.08 (0.25)	178	0.800 (2.625)	4495 (14747)
	1.52 (5.00)	168	0.800 (2.625)	4763 (15625)
	3.05 (10.00)	174	0.800 (2.625)	4598 (15086)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
	6.40 (21.00)	206	0.800 (2.625)	3884 (12743)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S12	0.08 (0.25)	185	0.800 (2.625)	4325 (14189)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	173	0.800 (2.625)	4625 (15173)
	4.57 (15.00)	169	0.800 (2.625)	4734 (15533)
	5.79 (19.00)	244	0.800 (2.625)	3279 (10758)
S13	0.08 (0.25)	178	0.800 (2.625)	4495 (14747)
	1.52 (5.00)	179	0.800 (2.625)	4470 (14665)
	3.05 (10.00)	187	0.800 (2.625)	4279 (14037)
	4.57 (15.00)	181	0.800 (2.625)	4420 (14503)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S14	0.08 (0.25)	176	0.800 (2.625)	4546 (14915)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	174	0.800 (2.625)	4598 (15086)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	5.72 (18.75)	172	0.800 (2.625)	4652 (15262)
S15	0.08 (0.25)	173	0.800 (2.625)	4625 (15173)
	1.52 (5.00)	166	0.800 (2.625)	4820 (15813)
	3.05 (10.00)	165	0.800 (2.625)	4849 (15909)
	4.57 (15.00)	168	0.800 (2.625)	4763 (15625)
	5.72 (18.75)	167	0.800 (2.625)	4791 (15719)
S16	0.08 (0.25)	spall	0.800 (2.625)	ERR *[2]
	1.52 (5.00)	276	0.800 (2.625)	2899 (9511)*[1]
	3.05 (10.00)	357	0.800 (2.625)	2241 (7353)*[1]
	4.57 (15.00)	396	0.800 (2.625)	2020 (6629)*[1]
	6.10 (20.00)	397	0.800 (2.625)	2015 (6612)*[1]
	6.55 (21.50)	200	0.800 (2.625)	4001 (13125)
S17	0.08 (0.25)	180	0.800 (2.625)	4445 (14583)
	1.52 (5.00)	179	0.800 (2.625)	4470 (14665)
	3.05 (10.00)	182	0.800 (2.625)	4396 (14423)[1]
	4.57 (15.00)	spall	0.800 (2.625)	ERR *[12]

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S17	5.64 (18.50)	spall	0.800 (2.625)	ERR*[2]
S18	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	250	0.800 (2.625)	3200 (10500)*[3]
	3.05 (10.00)	167	0.800 (2.625)	4791 (15719)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	550	0.800 (2.625)	1455 (4773)*[1]
	6.40 (21.00)	192	0.800 (2.625)	4167 (13672)[1]
S19	0.08 (0.25)	171	0.800 (2.625)	4679 (15351)
	1.52 (5.00)	171	0.800 (2.625)	4679 (15351)
	3.05 (10.00)	172	0.800 (2.625)	4652 (15262)
	4.57 (15.00)	175	0.800 (2.625)	4572 (15000)
	5.79 (19.00)	171	0.800 (2.625)	4679 (15351)
S20	0.08 (0.25)	spalled	0.800 (2.625)	ERR*
	1.52 (5.00)	spalled	0.800 (2.625)	ERR*
	3.05 (10.00)	spalled	0.800 (2.625)	ERR*
	4.57 (15.00)	spalled	0.800 (2.625)	ERR*
	6.10 (20.00)	spalled	0.800 (2.625)	ERR*
S21	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	178	0.800 (2.625)	4495 (14747)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	179	0.800 (2.625)	4470 (14665)
	6.10 (20.00)	180	0.800 (2.625)	4445 (14583)
S22	0.08 (0.25)	181	0.800 (2.625)	4420 (14503)
	1.52 (5.00)	183	0.800 (2.625)	4372 (14344)
	3.05 (10.00)	182	0.800 (2.625)	4396 (14423)
	4.57 (15.00)	184	0.800 (2.625)	4348 (14266)
	6.10 (20.00)	200	0.800 (2.625)	4001 (13125)
S23	0.08 (0.25)	190	0.800 (2.625)	4211 (13816)
	1.52 (5.00)	176	0.800 (2.625)	4546 (14915)
	3.05 (10.00)	179	0.800 (2.625)	4470 (14665)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S23	4.57 (15.00)	180	0.800 (2.625)	4445 (14583)
	6.10 (20.00)	179	0.800 (2.625)	4470 (14665)
S24	0.08 (0.25)	181	0.800 (2.625)	4420 (14503)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	177	0.800 (2.625)	4520 (14831)
	6.10 (20.00)	173	0.800 (2.625)	4625 (15173)
S25	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	175	0.800 (2.625)	4572 (15000)
	3.05 (10.00)	178	0.800 (2.625)	4495 (14747)
	4.88 (16.00)	181	0.800 (2.625)	4420 (14503)
	6.10 (20.00)	179	0.800 (2.625)	4470 (14665)
S26	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	176	0.800 (2.625)	4546 (14915)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	0.08 (0.25)	178	0.800 (2.625)	4495 (14747)
	1.52 (5.00)	179	0.800 (2.625)	4470 (14665)
S27	3.05 (10.00)	174	0.800 (2.625)	4598 (15086)
	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	5.79 (19.00)	172	0.800 (2.625)	4652 (15262)
	0.08 (0.25)	170	0.800 (2.625)	4706 (15441)
	1.52 (5.00)	NR	0.800 (2.625)	ERR*[1]
S28	3.05 (10.00)	181	0.800 (2.625)	4420 (14503)
	4.57 (15.00)	182	0.800 (2.625)	4396 (14423)
	6.10 (20.00)	184	0.800 (2.625)	4348 (14266)
	0.08 (0.25)	182	0.800 (2.625)	4396 (14423)
	1.52 (5.00)	184	0.800 (2.625)	4348 (14266)
S29	0.08 (0.25)	185	0.800 (2.625)	4325 (14189)
	1.52 (5.00)	175	0.800 (2.625)	4572 (15000)
	3.05 (10.00)	240	0.800 (2.625)	3334 (10938)*

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S29	4.57 (15.00)	179	0.800 (2.625)	4470 (14665)
	6.10 (20.00)	175	0.800 (2.625)	4572 (15000)
S30	0.08 (0.25)	305	0.800 (2.625)	2623 (8607)*3
	1.52 (5.00)	178	0.800 (2.625)	4495 (14747)
	3.05 (10.00)	172	0.800 (2.625)	4652 (15262)
	4.57 (15.00)	175	0.800 (2.625)	4572 (15000)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S31	0.08 (0.25)	173	0.800 (2.625)	4625 (15173)
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	173	0.800 (2.625)	4625 (15173)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	470	0.800 (2.625)	1702 (5585)*1
S32	0.08 (0.25)	176	0.800 (2.625)	4546 (14915)
	1.52 (5.00)	170	0.800 (2.625)	4706 (15441)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.10 (20.00)	184	0.800 (2.625)	4348 (14266)
S33	0.08 (0.25)	359	0.800 (2.625)	2229 (7312)*3
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	193	0.800 (2.625)	4146 (13601)
S34	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	169	0.800 (2.625)	4734 (15533)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	174	0.800 (2.625)	4598 (15086)
	6.10 (20.00)	171	0.800 (2.625)	4679 (15351)
S35	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	166	0.800 (2.625)	4820 (15813)
	3.05 (10.00)	163	0.800 (2.625)	4909 (16104)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S35	4.88 (16.00)	169	0.800 (2.625)	4734 (15533)
	6.10 (20.00)	179	0.800 (2.625)	4470 (14665)
S36	0.08 (0.25)	179	0.800 (2.625)	4470 (14665)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	174	0.800 (2.625)	4598 (15086)
	6.10 (20.00)	175	0.800 (2.625)	4572 (15000)
S37	0.08 (0.25)	176	0.800 (2.625)	4546 (14915)
	1.52 (5.00)	169	0.800 (2.625)	4734 (15533)
	3.05 (10.00)	167	0.800 (2.625)	4791 (15719)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.10 (20.00)	185	0.800 (2.625)	4325 (14189)
S38	0.08 (0.25)	179	0.800 (2.625)	4470 (14665)
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	173	0.800 (2.625)	4625 (15173)
	4.57 (15.00)	176	0.800 (2.625)	4546 (14915)
	6.10 (20.00)	179	0.800 (2.625)	4470 (14665)
S39	0.08 (0.25)	181	0.800 (2.625)	4420 (14503)
	1.52 (5.00)	165	0.800 (2.625)	4849 (15909)
	3.05 (10.00)	163	0.800 (2.625)	4909 (16104)
	4.57 (15.00)	168	0.800 (2.625)	4763 (15625)
	5.94 (19.50)	186	0.800 (2.625)	4302 (14113)
S40	0.08 (0.25)	172	0.800 (2.625)	4652 (15262)
	1.52 (5.00)	174	0.800 (2.625)	4598 (15086)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	178	0.800 (2.625)	4495 (14747)
	6.10 (20.00)	NR	0.800 (2.625)	ERR*[1]
S41	0.08 (0.25)	186	0.800 (2.625)	4302 (14113)[1]
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	166	0.800 (2.625)	4820 (15813)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S41	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	6.10 (20.00)	183	0.800 (2.625)	4372 (14344)
S42	0.08 (0.25)	393	0.800 (2.625)	2036 (6679)*[1]
	1.52 (5.00)	165	0.800 (2.625)	4849 (15909)
	3.05 (10.00)	167	0.800 (2.625)	4791 (15719)
	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S43	0.08 (0.25)	186	0.800 (2.625)	4302 (14113)
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	177	0.800 (2.625)	4520 (14831)
S44	0.08 (0.25)	179	0.800 (2.625)	4470 (14665)
	1.52 (5.00)	177	0.800 (2.625)	4520 (14831)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	178	0.800 (2.625)	4495 (14747)
	6.10 (20.00)	175	0.800 (2.625)	4572 (15000)
S45	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	176	0.800 (2.625)	4546 (14915)
	3.05 (10.00)	173	0.800 (2.625)	4625 (15173)
	4.88 (16.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S46	0.08 (0.25)	187	0.800 (2.625)	4279 (14037)
	1.52 (5.00)	171	0.800 (2.625)	4679 (15351)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	175	0.800 (2.625)	4572 (15000)
	6.10 (20.00)	186	0.800 (2.625)	4302 (14113)
S47	0.08 (0.25)	179	0.800 (2.625)	4470 (14665)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	175	0.800 (2.625)	4572 (15000)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S47	4.57 (15.00)	174	0.800 (2.625)	4598 (15086)
	5.79 (19.00)	177	0.800 (2.625)	4520 (14831)
S48	0.08 (0.25)	182	0.800 (2.625)	4396 (14423)
	1.52 (5.00)	175	0.800 (2.625)	4572 (15000)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	179	0.800 (2.625)	4470 (14665)
	5.79 (19.00)	181	0.800 (2.625)	4420 (14503)
S49	0.08 (0.25)	spalled	0.800 (2.625)	ERR*
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	166	0.800 (2.625)	4820 (15813)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.10 (20.00)	172	0.800 (2.625)	4652 (15262)
S50	0.08 (0.25)	176	0.800 (2.625)	4546 (14915)
	1.52 (5.00)	176	0.800 (2.625)	4546 (14915)
	3.05 (10.00)	174	0.800 (2.625)	4598 (15086)
	4.57 (15.00)	175	0.800 (2.625)	4572 (15000)
	6.10 (20.00)	177	0.800 (2.625)	4520 (14831)
S51	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	177	0.800 (2.625)	4520 (14831)
	6.10 (20.00)	187	0.800 (2.625)	4279 (14037)
S52	0.08 (0.25)	spalled	0.800 (2.625)	ERR*
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	178	0.800 (2.625)	4495 (14747)
	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	6.10 (20.00)	390	0.800 (2.625)	2052 (6731)*[3]
S53	0.08 (0.25)	357	0.800 (2.625)	2241 (7353)*[3]
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	168	0.800 (2.625)	4763 (15625)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S53	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.10 (20.00)	184	0.800 (2.625)	4348 (14266)
S54	0.08 (0.25)	170	0.800 (2.625)	4706 (15441)
	1.52 (5.00)	172	0.800 (2.625)	4652 (15262)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.02 (19.75)	172	0.800 (2.625)	4652 (15262)
S 55	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	175	0.800 (2.625)	4572(15000)
	5.18 (17.00)	175	0.800 (2.625)	4572 (15000)
	6.10 (20.00)	181	0.800 (2.625)	4420 (14503)
S56	0.08 (0.25)	182	0.800 (2.625)	4396 (14423)
	1.52 (5.00)	174	0.800 (2.625)	4598 (15086)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.02 (19.75)	176	0.800 (2.625)	4546 (14915)
S57	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	171	0.800 (2.625)	4679 (15351)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	172	0.800 (2.625)	4652 (15262)
	6.02 (19.75)	204	0.800 (2.625)	3922 (12868)
S58	0.08 (0.25)	247	0.800 (2.625)	3239 (10628)*
	1.52 (5.00)	171	0.800 (2.625)	4679 (15351)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	170	0.800 (2.625)	4706 (15441)
	6.02 (19.75)	182	0.800 (2.625)	4396 (14423)
S59	0.08 (0.25)	430	0.800 (2.625)	1861 (6105)*[3]
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length m (ft)	Pulse Velocity m/s (ft/s)
Monolith	Distance from West End of Monolith m (ft)			
S59	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	5.94 (19.50)	168	0.800 (2.625)	4763 (15625)
S60	0.08 (0.25)	273	0.800 (2.625)	2931 (9615)*
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	167	0.800 (2.625)	4791 (15719)
	4.57 (15.00)	166	0.800 (2.625)	4820 (15813)
	6.02 (19.75)	173	0.800 (2.625)	4625 (15173)
S61	0.08 (0.25)	173	0.800 (2.625)	4625 (15173)
	1.52 (5.00)	170	0.800 (2.625)	4706 (15441)
	3.05 (10.00)	169	0.800 (2.625)	4734 (15533)
	4.57 (15.00)	167	0.800 (2.625)	4791 (15719)
	5.94 (19.50)	172	0.800 (2.625)	4652 (15262)
S62	0.08 (0.25)	179	0.800 (2.625)	4470 (14665)
	1.52 (5.00)	166	0.800 (2.625)	4820 (15813)
	3.05 (10.00)	168	0.800 (2.625)	4763 (15625)
	4.57 (15.00)	169	0.800 (2.625)	4734 (15533)
	5.94 (19.50)	176	0.800 (2.625)	4546 (14915)
S63	0.08 (0.25)	238	0.800 (2.625)	3362 (11029)*[3]
	1.52 (5.00)	169	0.800 (2.625)	4734 (15533)
	3.05 (10.00)	168	0.800 (2.625)	4763 (15625)
	4.57 (15.00)	168	0.800 (2.625)	4763 (15625)
	6.10 (20.00)	320	0.800 (2.625)	2500 (8203)*[3]
S64	0.08 (0.25)	178	0.800 (2.625)	4495 (14747)
	1.52 (5.00)	170	0.800 (2.625)	4706 (15441)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	175	0.800 (2.625)	4572 (15000)
S65	0.08 (0.25)	178	0.800 (2.625)	4495 (14747)
	1.52 (5.00)	173	0.800 (2.625)	4625 (15173)
	3.05 (10.00)	171	0.800 (2.625)	4679 (15351)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length M (ft)	Pulse Velocity M/s (ft/s)
Monolith	Distance from West End of Monolith M (ft)			
S65	4.88 (16.00)	180	0.800 (2.625)	4445 (14583)
	5.94 (19.50)	176	0.800 (2.625)	4546 (14915)
S66	0.08 (0.25)	177	0.800 (2.625)	4520 (14831)
	1.52 (5.00)	171	0.800 (2.625)	4679 (15351)
	3.05 (10.00)	175	0.800 (2.625)	4572 (15000)
	4.57 (15.00)	175	0.800 (2.625)	4572 (15000)
	6.02 (19.75)	180	0.800 (2.625)	4445 (14583)
S67	0.08 (0.25)	503	0.800 (2.625)	1591 (5219)*[1]
	1.52 (5.00)	169	0.800 (2.625)	4734 (15533)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	170	0.800 (2.625)	4706 (15441)
	6.02 (19.75)	245	0.800 (2.625)	3266 (10714)*[1]
S68	0.08 (0.25)	172	0.800 (2.625)	4652 (15262)
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	168	0.800 (2.625)	4763 (15625)
	4.57 (15.00)	171	0.800 (2.625)	4679 (15351)
	6.02 (19.75)	171	0.800 (2.625)	4679 (15351)
S69	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	167	0.800 (2.625)	4791 (15719)
	3.05 (10.00)	170	0.800 (2.625)	4706 (15441)
	4.57 (15.00)	169	0.800 (2.625)	4734 (15533)
	6.02 (19.75)	172	0.800 (2.625)	4652 (15262)
S70	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	174	0.800 (2.625)	4598 (15086)
	3.05 (10.00)	177	0.800 (2.625)	4520 (14831)
	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S71	0.08 (0.25)	175	0.800 (2.625)	4572 (15000)
	1.52 (5.00)	174	0.800 (2.625)	4598 (15086)
	3.05 (10.00)	177	0.800 (2.625)	4520 (14831)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Table A-2
Pulse Velocity Measurements from South Seawall

Location		Time of Arrival microseconds	Path Length M (ft)	Pulse Velocity M/s (ft/s)
Monolith	Distance from West End of Monolith M (ft)			
S71	4.57 (15.00)	173	0.800 (2.625)	4625 (15173)
	6.10 (20.00)	178	0.800 (2.625)	4495 (14747)
S72	0.08 (0.25)	spalled	0.800 (2.625)	ERR*
	1.52 (5.00)	174	0.800 (2.625)	4598 (15086)
	3.05 (10.00)	176	0.800 (2.625)	4546 (14915)
	4.57 (15.00)	170	0.800 (2.625)	4706 (15441)
	6.10 (20.00)	spalled	0.800 (2.625)	ERR*
S73	0.08 (0.25)	176	0.800 (2.625)	4546 (14915)
	0.91 (3.00)	168	0.800 (2.625)	4763 (15625)
	1.83 (6.00)	170	0.800 (2.625)	4706 (15441)
	2.13 (7.00)	131	0.800 (2.040)	4750 (15585)
	3.35 (11.00)	137	0.800 (2.040)	4542 (14903)
	4.88 (16.00)	135	0.800 (2.040)	4610 (15124)
	6.40 (21.00)	133	0.800 (2.040)	4679 (15351)

*Low Measurement [1]Spalled [2] Edge Delamination [3] Cracked

Appendix B
Petrographic Examination

Corps of Engineers, USAE Waterways Experiment Station	Concrete Report	Structures Laboratory 3909 Halls Ferry Road Vicksburg, MS 39180
Project: Perry's Victory Monument, Seawall		Date: August 2, 1995

Samples

I. Twenty seven, 102-mm (4-in.) diameter cores taken from top of seawalls were received for examination and testing to determine the cause of cracking in the concrete. The cores were assigned CTD serial numbers as described in Table B-1. These serial numbers will be used to describe the samples examined and tested.

Table B-1
Core Samples

CTD Sample No.	Field Id.	CTD Sample No.	Field Id.
950372	S7	950386	S68
950373	S8	950387	S72
950374	S16	950388	N10
950375	S16/17	950389	N11
950376	S17	950390	N21
950377	S17B	950391	N22
950378	S27	950392	N30
950379	S20	950393	N38
950380	S37	950394	N45
950381	S49	950395	N56
950382	S52A	950396	N57
950383	S52B	950397	N34, old seawall
950384	S60A	950398	N40, old seawall
950385	S60B		

Procedure

II. A log was made of each core describing the general composition and condition of the concrete. Generally intact pieces of core having a length to diameter ratio of 2:1 were designated for compressive-strength test specimens. They were indicated on the core logs as C/S. Selected samples were examined in more detail using guidance from "Standard Practice for Petrographic Examination of Hardened Concrete," CRD-C 57 (ASTM C 856).

III. Slabs cut from cores were prepared according to "Standard Practice for Microscopical Determination of Air-Void Content and Parameters of the Air-Void System in Hardened Concrete," CRD-C 42 (ASTM C 457) and tested to determine the air-void parameters of the concrete.

IV. Specific gravities and absorption values were determined for selected individual aggregate particles removed from cores. Determinations were made according to "Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate," CRD-C 107 (ASTM C 127).

Results

V. The cores consisted of concrete from the north, south, and old seawalls (logs of core are presented in Figures B-1 through B-27). Concrete from both north and south seawalls were similar in composition. Both consisted of air-entrained concrete, made using crushed and natural limestone coarse aggregates, and natural limestone fine aggregate. All showed no segregation and generally good consolidation. The individual descriptions are shown in the logs. Many of the cores contained open fractures running along the length of the core as well as normal to its length. In some cores the fractures were random, diagonal and in some, the cores had separated into rubble during the coring operation (Figures B-28 through B-31).

VI. Many of the fractures were parallel to subparallel cracks. Some tended to be subparallel to the surface of the structure. Examination of photographs show the cracks and fractures are at edges, corners, and near exposed surfaces. Some of the cores show incipient fractures with only a slight indication of crack propagation while other were open and others consisted of multiple cracks causing the concrete to be rubble.

VII. Some of the deterioration in the form of cracking went to full depth of the core having 0.46 m (1.5 ft) depths. More commonly the depth of deterioration was limited to about 0.15 m (0.5 ft).

VIII. The old seawall concrete (950397 and 950398) contained a natural siliceous coarse aggregate and a natural siliceous fine aggregate. It contained

some entrained air voids. Examination of aggregate particles indicated some to be low refractive index chert.

IX. Reaction rims were observed in coarse aggregate of the concrete from the north and south seawalls. When acid was used to etch the particles, some showed negative rimming in which the rims more easily dissolved but most rims showed no relief when etched.

X. White reaction products were common in cracks. Some of the reaction completely filled air voids. Reaction product filling voids was identified as ettringite. Alkali-silica reaction (ASR) gel was present in limited amounts in some cracks. ASR gel was abundant in the concrete from the old seawall in which the fractured surfaces were coated with material.

XI. Coarse aggregate particles were mostly dolomitic limestone with some containing trace amounts of clay and some quartz (X-ray diffraction patterns are shown in Figures B-32 through B-44). Some contained only dolomite as a mineral constituent.

XII. Reinforcing steel for the most part was free of corrosion products. Only slight corrosion was observed on the steel in the cores.

XIII. The concrete contained some entrained air in both the old and recent concrete (Table B-2). It however shows a wide range of total air ranging from a high of near six percent to a low of near one percent. Spacing factors show a range of 0.780 to 0.213 mm (0.0307 to 0.0084 in.). Sample 950375A and 950375B were from a core drilled through a joint representing concrete from monoliths S16 and S17 of the south seawall. Adjacent monolith in this case showed spacing factors to be significantly different.

Table B-2
Characteristics of Concrete

Parameters	Sample					
	950375A (S17)	950375B (S16)	950385 (S60B)	950398 (N40, Old Seawall)	950395 (N56)	950396 (N57)
Coarse Aggregate, %	45.6	26.3	41.0	36.7	32.3	38.6
Fine Aggregate, %	25.3	31.2	27.8	34.2	31.3	25.6
Paste, %	23.4	40.7	28.1	28.0	30.3	29.1
Entrained Voids, %	3.4	0.5	1.4	0.5	2.7	2.4
Entrapped Voids, %	2.3	1.3	1.7	0.6	3.4	4.3
Total Air, %	5.7	1.8	3.1	1.1	6.1	6.7
Spacing Factor, mm (in.)	0.213 (0.0084)	0.789 (0.0307)	0.470 (0.0185)	0.282 (0.0111)	0.236 (0.0093)	0.335 (0.0132)

XIV. Specific gravities for the coarse aggregate ranged from a low of 2.16 to a high of 2.89 (Table B-3). Absorption correlated with specific gravity in that particles with low specific gravities also indicated high absorption. Absorption ranged from less than 1 percent to more than 11 percent. Bulk specific gravities for the particles as well as absorptions are presented below:

Table B-3
Specific Gravities and Absorption of Coarse Aggregate

Sample Id.	Bulk Specific Gravity	Absorption, %
A	2.36	4.82
B	2.42	4.43
C	2.16	11.29
A	2.39	5.08
A	2.12	6.98
B	2.63	1.85
C	2.57	1.74
D	2.89	0.52
E	2.53	3.36
A	2.55	0.65
B	2.26	1.46
C*	2.60	1.44
A	2.34	5.94
B	2.20	9.09
AVERAGE	2.45	4.45

*Surface popout

Conclusion and Discussions

XV. Concrete deterioration is most likely related to lack of resistance to freezing and thawing while critically saturated. Entrained air should provide a spacing factor of 0.203 mm (0.008 in.) or less to provide adequate protection from stresses associated with freezing and thawing of critically saturated concrete. Examination of concrete in adjacent monoliths show that one may be protected while the other may be susceptible to freezing and thawing deterioration.

XVI. Aggregate particles with low specific gravities and high absorption usually are not resistant to freezing and thawing. In many places specific gravities of less than

2.40 are indications of potential problem aggregates. Some of the aggregates had high absorption and could be traced to some durability problems as popouts were observed on concrete surfaces. Problems associated with nondurable aggregate in this case would be associated with edges and corners where the concrete has the highest potential for saturation.

XVII. The dolomitic limestone shows some reaction rims around aggregate particles indicating some alkali-carbonate rock reaction. This reaction does not appear to be a problem as there was no evidence joint closure in the structure or possible displacement.

XVIII. Some alkali-silica reaction was observed in some near surface cracks. The gel in the recent concrete was limited to partially coating some fractures and appears to be very limited in extent. Alkali-silica reaction was much more extensive in one core representing the concrete from old seawall and was not evident in the core that was intact. The concrete was rubble where ASR was observed in the old concrete. ASR may be a major deteriorating cause in the old concrete.

XIX. Corrosion of steel was minor and does not appear to be sufficient in the limited samples taken to be a cause of concrete cracking. As the structure ages and the concrete along open cracks and adjacent to the steel carbonates thus reducing the pH in the concrete around the steel and the open channel allows water and air penetration, corrosion of steel could become a problem causing spalling and staining of the concrete.

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N34	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Rubble Located at joint 34/35 ASR Coated Surface Siliceous FA natural CA fracture particles CTD #950397 _____ Petrography - Chert coarse aggregate Some entrained air voids Voids filled with ASR gel and ettringite		N34	

Figure B-10. Log for North seawall core N34 (Old Seawall)

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N57	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.4 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface		N57	
-1.4	1.40		EOB 1.4-ft Located at joint 57/58 1 1/2-in max size natural/ crushed Ls CA Natural Ls FA Numerous entrapped air Air entrained No segregation CTD #950396			

Figure B-9. Log for north seawall core N57

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N56	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.4 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Petrography Open crack to 2-in depth Incipient crack length of core C/S		N56	
-1.4	1.40		EOB 1.4-ft new Located at joint 56/57 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950395			

Figure B-8. Log for north seawall core N56

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N45	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.3 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Surface crack No real vertical extention C/S		N45	
-1.3	1.30		EOB 1.3-ft new Located at joint 44/45 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Some entrapped voids Air entrained No segregation CTD #950394			

Figure B-7. Log for north seawall core N45

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N38	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.6 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface		N38	
-0.6	0.60		EOB 0.6-ft Located at joint 37/38 Incipient cracks length of core through CA 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Some entrained voids No segregation CTD #950393			

Figure B-6. Log for north seawall core N38

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N30	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.3 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface C/S Petrography		N30	
-1.3	1.30		EOB 1.3-ft new Located at joint 29/30 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Some entrapped voids Air entrained No segregation CTD #950392 _____ Petrography - Acid etched shows no relief in reaction rims			

Figure B-5. Log for north seawall core N30

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N22	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.4 feet		19. SIGNATURE OF INSPECTOR	

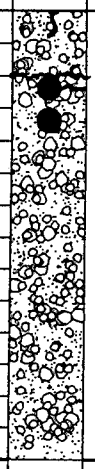
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface 2 pieces 3/4-in rein-forcing steel Poor consolidation around steel Minor corrosing of upper bar		N22	
-1.4	1.40		EOB 1.4-ft new Located at ladder recess 1 1/2-in max size natural/ crushed Ls CA Natural Ls FA Air entrained Numerous entrapped air No segregation Vertical and horizontal incipient cracks Cracks go through CA Reaction rim around some CA CTD #950391			

Figure B-4. Log for north seawall core N22

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N21	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.65 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface Fracture to 1-in depth C/S C/S		N21	
-1.65	1.65		EOB 1.65-ft new Located near mid-length of monolith 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950390			

Figure B-3. Log for north seawall core N21

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.2 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface White exudation in surface cracks Incipient fracture to 1.5-in Crack at .20-ft is old C/S		N11	
-1.2	1.2		EOB 1.2-ft new Located at joint 11/12 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Some entrapped air Air entrained air CTD #950389 Petrography - Exudation material is ASR			

Figure B-2. Log for north seawall core N11

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N10	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Rubble Located at joint 9/10 Total Disintergration Gravel size pieces CTD #950388		N10	

Figure B-1. Log for north seawall core N10

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	N40	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.35 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0		Eroded Surface Siliceous FA standing in relief, some scaling		N40	
-0.35	0.35		EOB 0.35-ft Located at joint 40/41 1-in max. size siliceous natural CA Siliceous FA Good consolidation No segregation CTD #950398			

Figure B-11. Log for north seawall core N40 (Old Seawall)

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S7	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.25 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface		S7	
-0.25	0.25		EOB 0.25-ft Located at joint 7/8 White reaction product on paste surface 0-0.2' is highly fractured 0.2-0.25' is rubble 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950372			

Figure B-12. Log for south seawall core S7

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) S8		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED 5-24-95	
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.55 feet		19. SIGNATURE OF INSPECTOR	

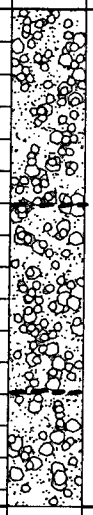
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface C/S C/S		S8	
-1.55	1.55		EOB 1.55-ft New Located near joint 7/8 1 1/2-in max. size crushed/ natural Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950373			

Figure B-13. Log for south seawall core S8

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S16	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.35 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface		S16	
-0.35	0.35		EOB 0.35-ft Located near joint 15/16 0-0.3'is highly fractured 0.3-0.35' is rubble 1-in max. size crushed/ natural Ls CA Natural Ls FA Some entrapped voids Air entrained No segregation CTD #950374			

Figure B-14. Log for south seawall core S16

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) S16/17		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.7 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface		S16	
-0.7	0.70		EOB 0.7-ft Located at joint 16/17 S17 (portion) intact 1-in max. size crushed/ natural Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation S16 (portion) Vertical & horizontal fractures through and around aggregates No or little entrained air Some entrapped air No segregation Aggregate like S17 CTD #950375			

Figure B-15. Log for south seawall core S16/17

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"		
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)		
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL		
4. HOLE NO. (As shown on drawing title and file number)	S17A	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A	UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES		
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER		
		16. DATE HOLE	STARTED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 0 feet		19. SIGNATURE OF INSPECTOR		

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Rubble Located at joint 17/18 Some vertical cracks through and around CA 1 1/2-in max. size natural crushed Ls CA Natural Ls FA Some entrapped voids Some entrained voids No segregation CTD #950376		S17A	

Figure B-16. Log for south seawall core S17A

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S17B	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.2 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Hairline crack to 1-in depth through aggregate C/S		S17B	
-1.2	1.20		EOB 1.2 New Located at joint 17/18 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950377			

Figure B-17. Log for south seawall core S17B

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) S20		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.2 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface		S20	
-0.2	0.20		EOB 0.2-ft Located at joint 19/20 Rubble Numerous entrapped voids Some entrained voids Some filled entrained voids Fractures through and around CA 1-in max. size natural/ crushed Ls CA Natural Ls FA CTD #950379 Petrography - White reaction was ettringite			

Figure B-18. Log for south seawall core S20

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) S27		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE STARTED / COMPLETED 5-24-95	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE 1.5 feet		18. TOTAL CORE RECOVERY FOR BORING	
		19. SIGNATURE OF INSPECTOR	

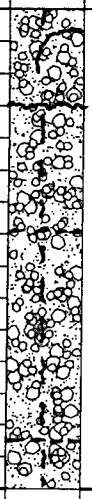
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Incipict fractures through and around CA C/S		S27	
-1.5	1.50		EOB 1.5 New Located at joint 27/28 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Some entrained air No segregation CTD #950378			

Figure B-19. Log for south seawall core S27

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S37	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.25 feet		19. SIGNATURE OF INSPECTOR	

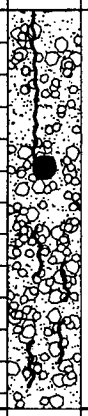
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface Vertical crack to rebar 7/8-in steel reinforcing bar, slightly rusty		S37	
-1.25	1.25		EOB 1.25-ft Located at joint 37/38 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Some entrained air No segregation CTD #950380 Petrography - Fractured nondurable aggregate is a porous dolomitic limestone			

Figure B-20. Log for south seawall core S37

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S49	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.55 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface		S49	
-0.55	0.55		EOB 0.55-ft Located at joint 48/49 Numerous incipient cracks through aggregate and paste 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Some entrapped air Some entrained air White reaction around CA CTD #950381 _____ Petrography - Acid etched of reaction rims shows no change in relief			

Figure B-21. Log for south seawall core S49

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"		
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)		
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL		
4. HOLE NO. (As shown on drawing title and file number)	S52A	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A	UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES		
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER		
		16. DATE HOLE	STARTED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 0.25 feet		19. SIGNATURE OF INSPECTOR		

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface		S52A	
-0.25	0.25		EOB approx. 0.25-ft Located at joint 51/52 Rubble Diagonal incipient fractures through aggregate and paste Numerous entrapped voids Some entrained air Some white reaction product in voids 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA CTD #950382 _____ Petrography - Many voids were filled with ettringite			

Figure B-22. Log for south seawall core S52A

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) S52B		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE STARTED / COMPLETED 5-24-95	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE 1 feet		18. TOTAL CORE RECOVERY FOR BORING	
		19. SIGNATURE OF INSPECTOR	

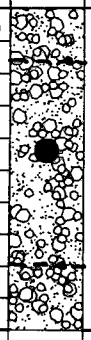
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.00		Finished top surface Petrography 1-in steel reinforcing bar C/S		S52B	
-1	1.00		EOB 1.0-ft new Located at joint 51/52 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA Some entrapped air Air entrained CTD #950383 Petrography - Acid etched indicated some negative reaction rims			

Figure B-23. Log for south seawall core S52B

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS

1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"		
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)		
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL		
4. HOLE NO. (As shown on drawing title and file number)	S60A	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A	UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES		
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER		
		16. DATE HOLE	STARTED	COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 0.5 feet		19. SIGNATURE OF INSPECTOR		

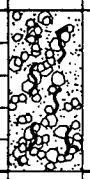
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface		S60A	
-0.5	0.50		EOB 0.5-ft Located at joint 59/60 Vertical incipient fracture 1 1/2-in max. size natural/ crushed Ls CA Natural Ls FA White reaction product around CA Some entrapped air Some entrained air No segregation CTD #950384 Petrography - White reaction product is ASR associated with low index chert			

Figure B-24. Log for south seawall core S60A

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S60B	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED 5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.1 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface Vertical incipient fractures through-out length of core (through CA particles)		S60B	
-1.1	1.10		EOB 1.1-ft Located at joint 59/60 1 1/2-in max size natural/ crushed Ls CA Natural Ls CA Some entrapped air Some entrained air Some white reaction products in voids CTD #950385 _____ Petrography - Coarse aggregate particles are porous			

Figure B-25. Log for south seawall core S60B

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S68	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED N/A / UNDISTURBED N/A
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.4 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface C/S		S68	
-1.4	1.40		EOB 1.4-ft new Located near mid-length of monolith 1 1/2-in size natural/ crushed Ls CA Natural Ls FA Some entrapped air Air entrained No segregation CTD #950386			

Figure B-26. Log for south seawall core S68

DRILLING LOG	DIVISION NAD	INSTALLATION	SHEET 1 OF 1 SHEETS
1. PROJECT Perry's Victory		10. SIZE AND TYPE OF BIT 4-in	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	S72	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ _____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE STARTED / COMPLETED	5-24-95
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 1.4 feet		19. SIGNATURE OF INSPECTOR	

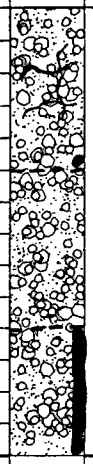
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface Numerous incipient fractures Reinforcing steel & tie wire, some corrosion C/S Short specimen Reinforcing steel, some corrosion		S72	
-1.4	1.4		EOB 1.4-ft new Located at joint 72/73 1-in size natural/ crushed Ls CA Natural Ls FA Numerous entrapped voids Air entrained No segregation CTD #950387			

Figure B-27. Log for south seawall core S72

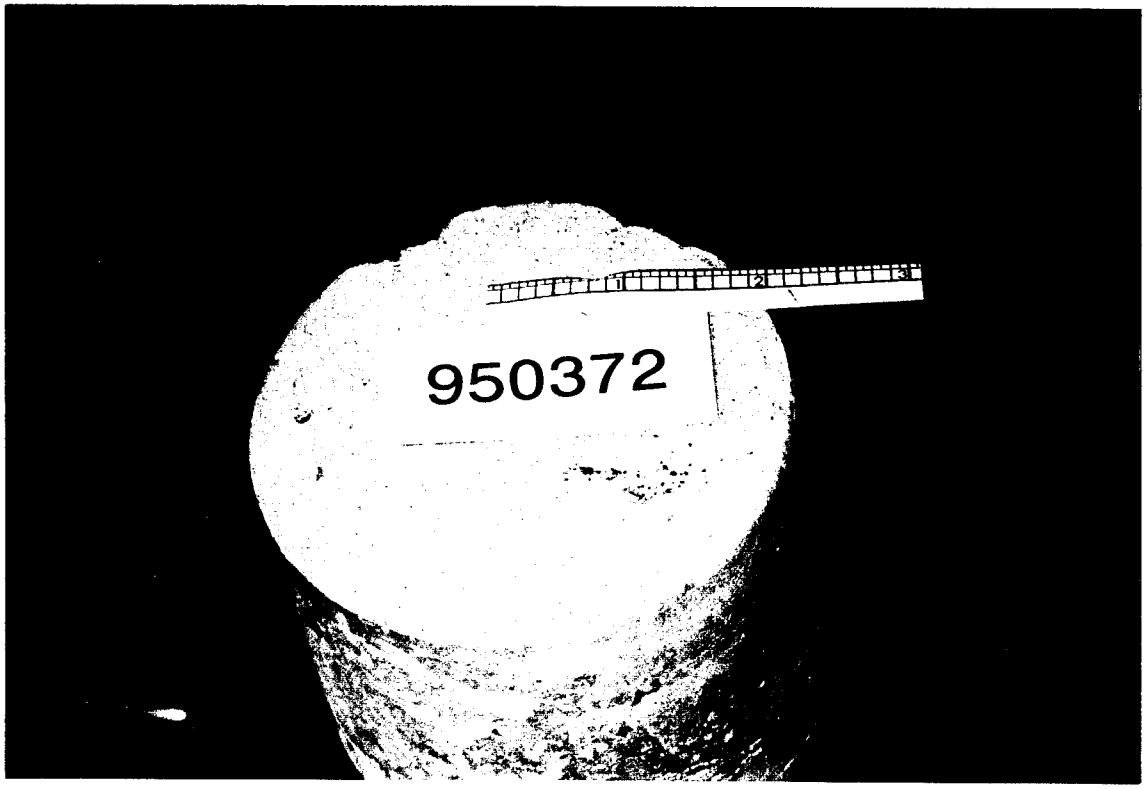


Figure B-28. Sample 950372 surface shows intact concrete

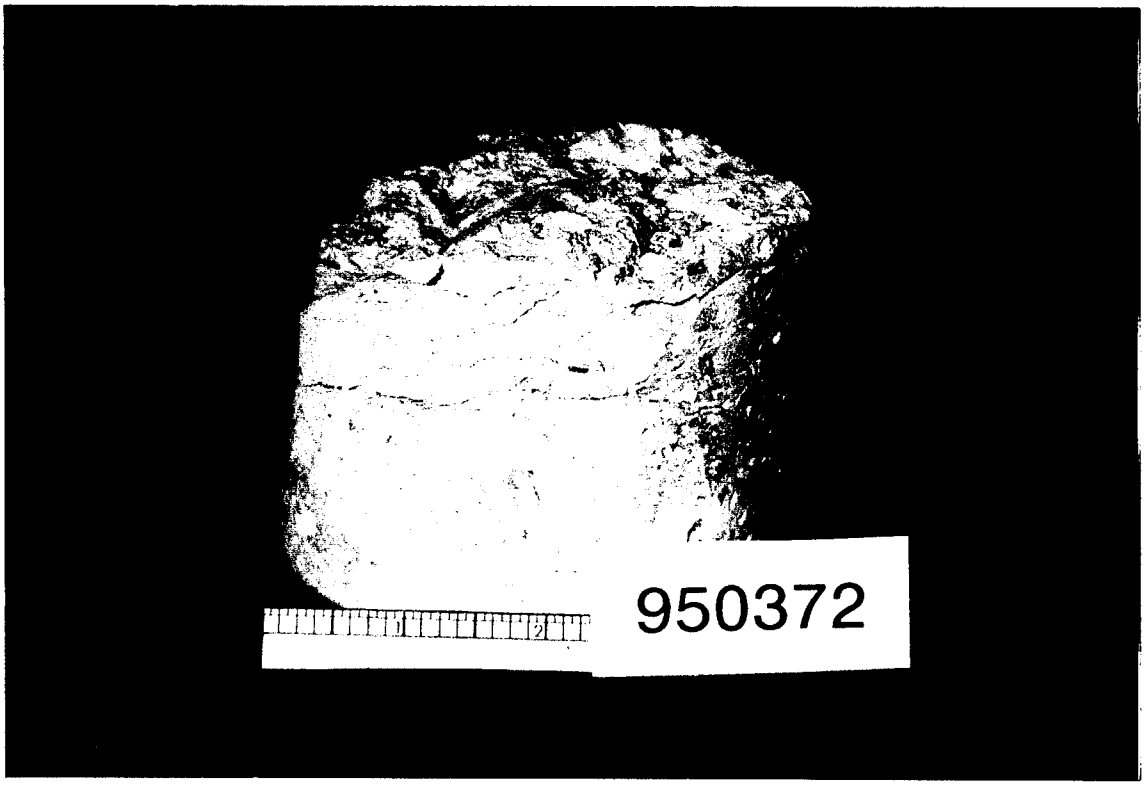


Figure B-29. Cracking parallel to top surface of structure (bottom of photo) occurs several inches below surface and cannot be detected by visual examination

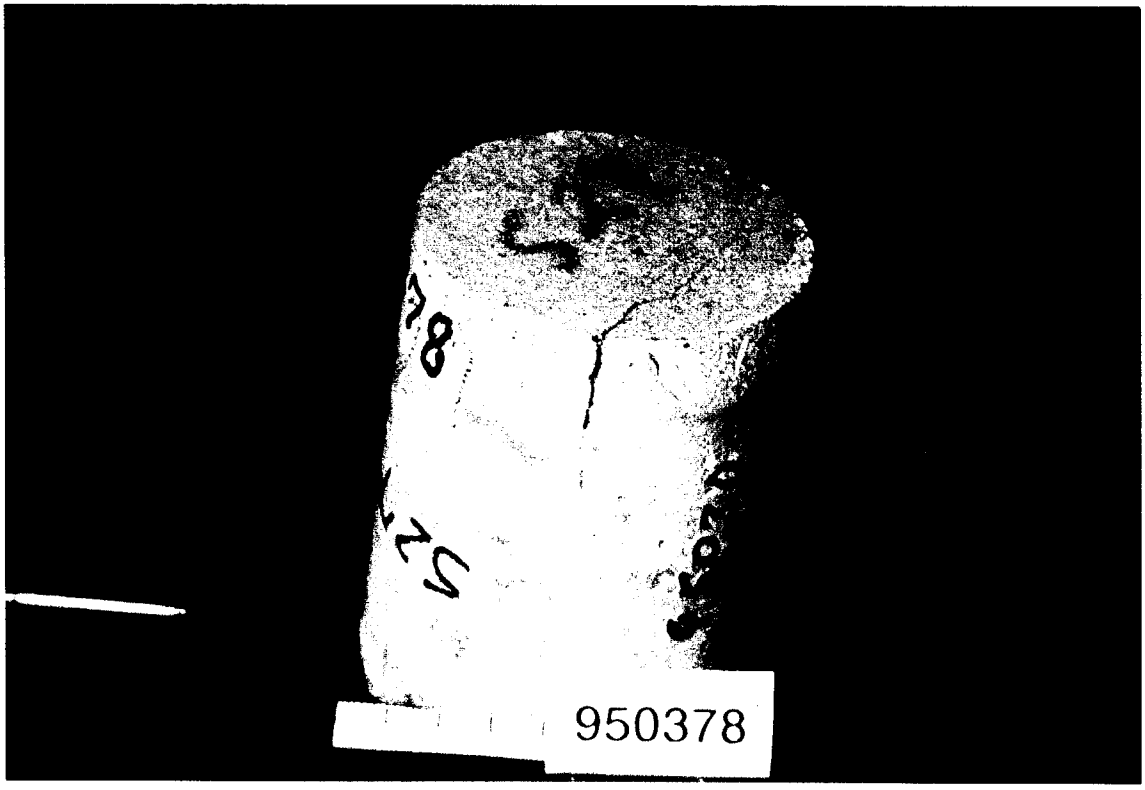


Figure B-30. Vertical crack in sample 950378 goes to the surface of the concrete

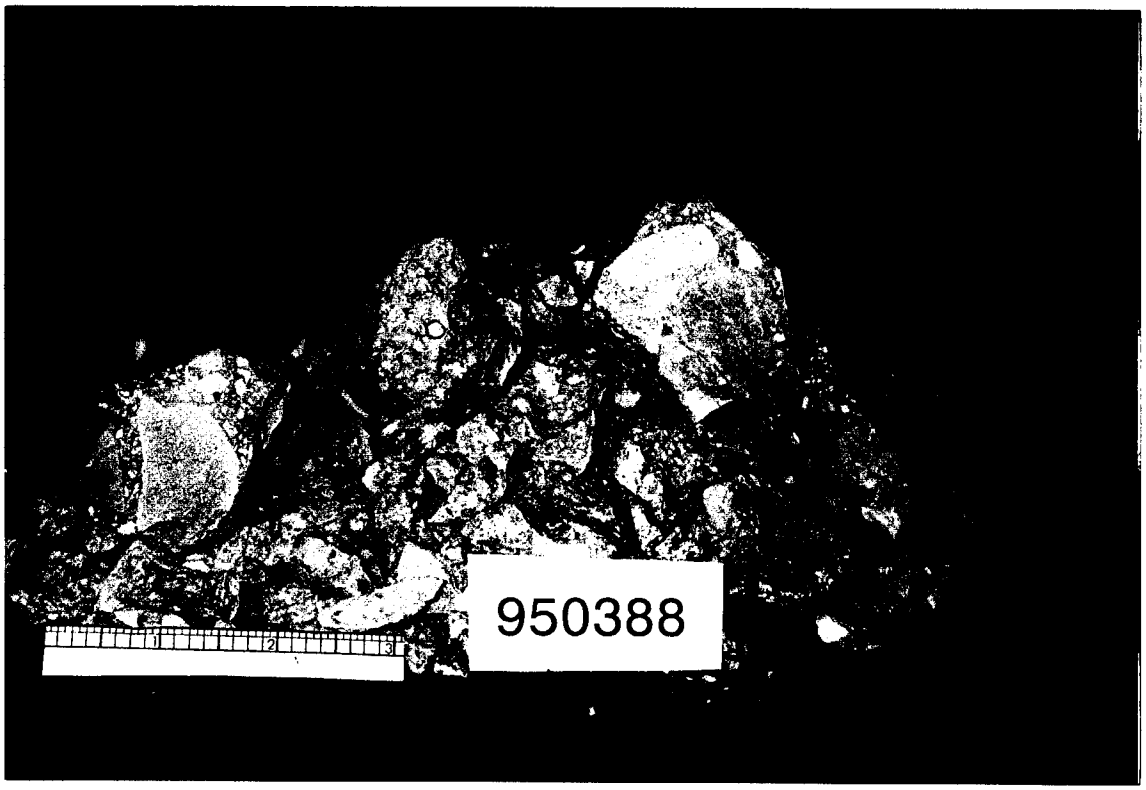


Figure B-31. Sample 950388 consists of rubble in which the fractures commonly go through aggregate particles as well as through paste

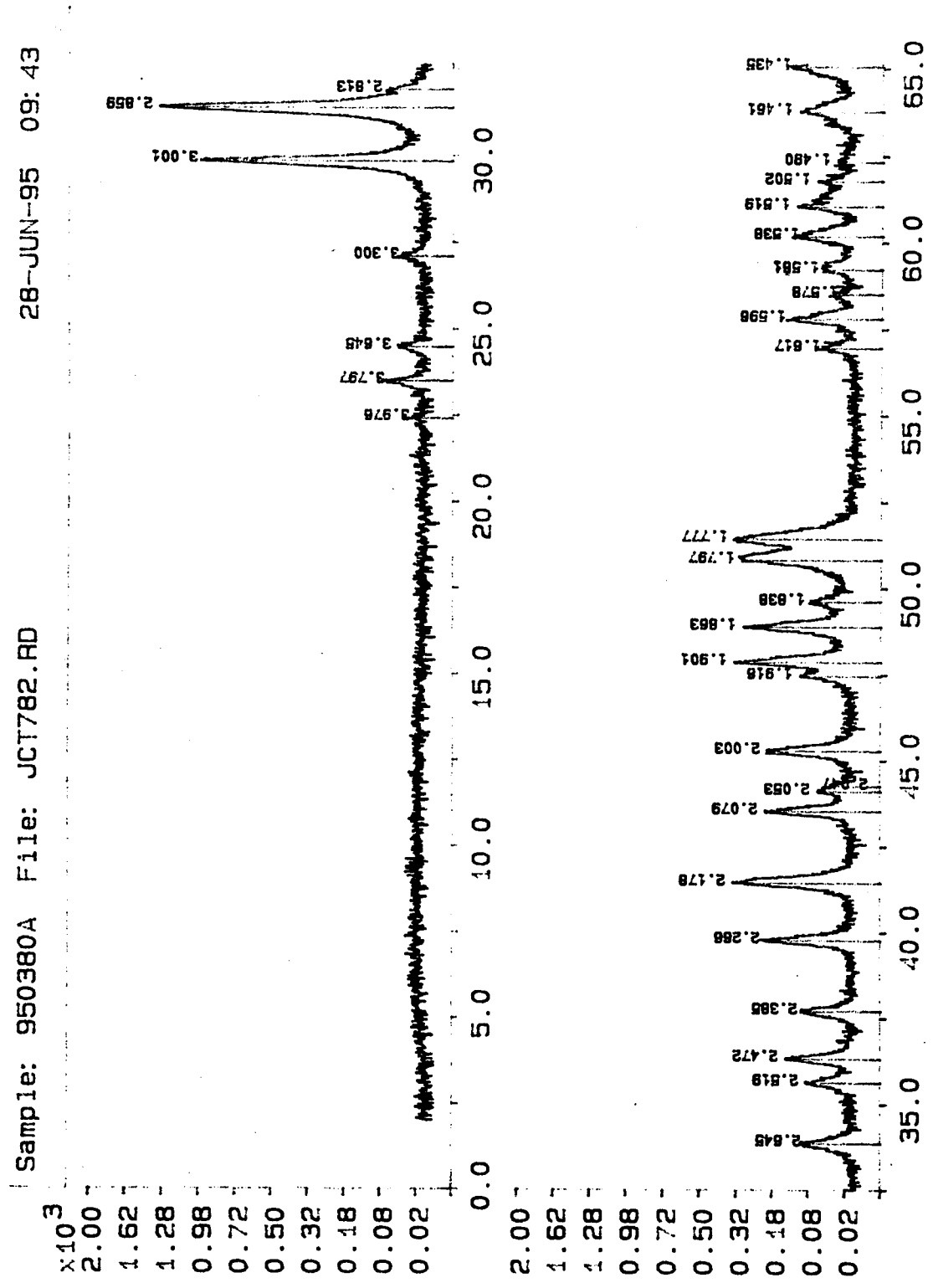


Figure B-32. X-ray diffraction patterns for Sample 950380A

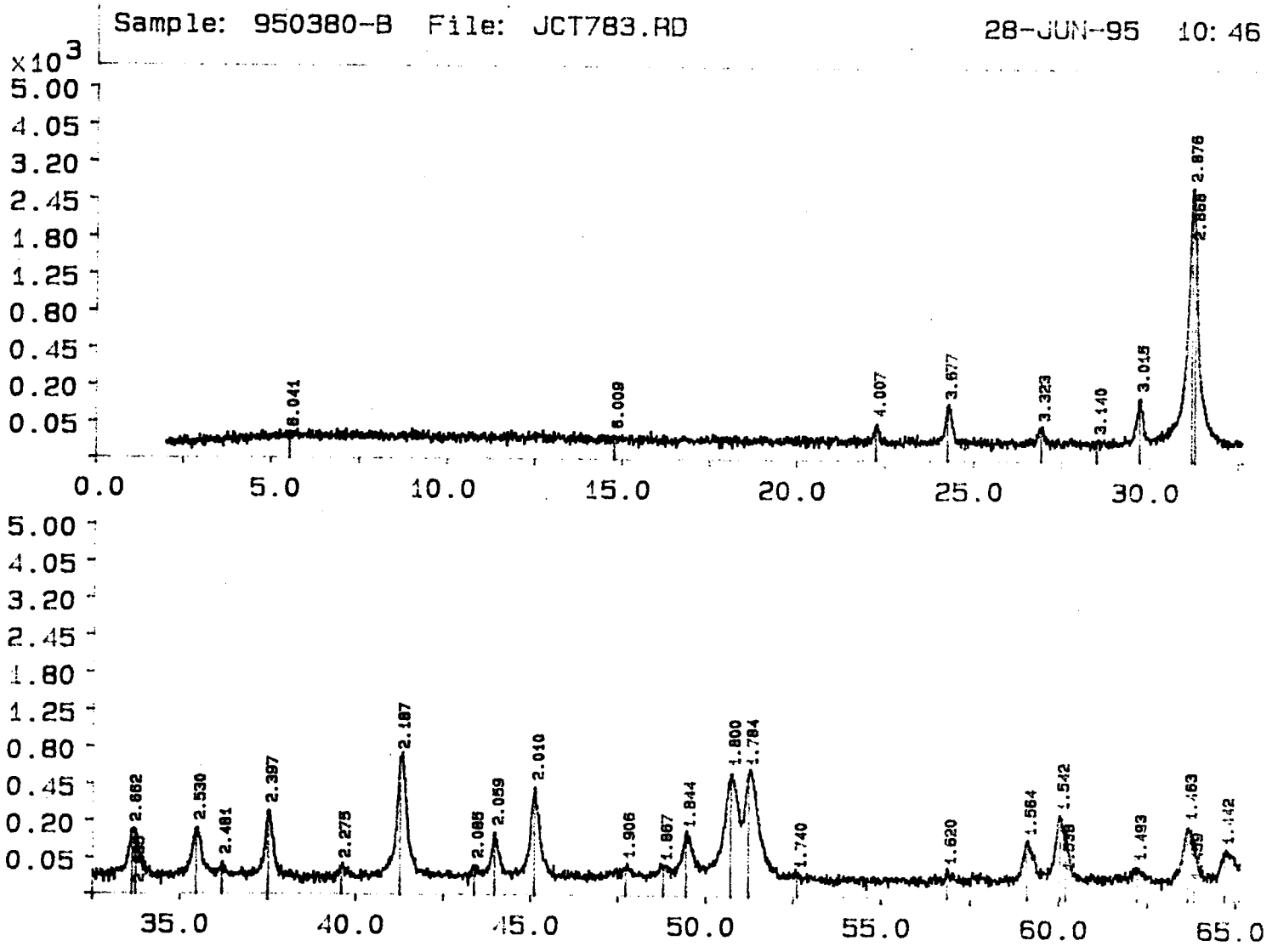


Figure B-33. X-ray diffraction patterns for Sample 950380B

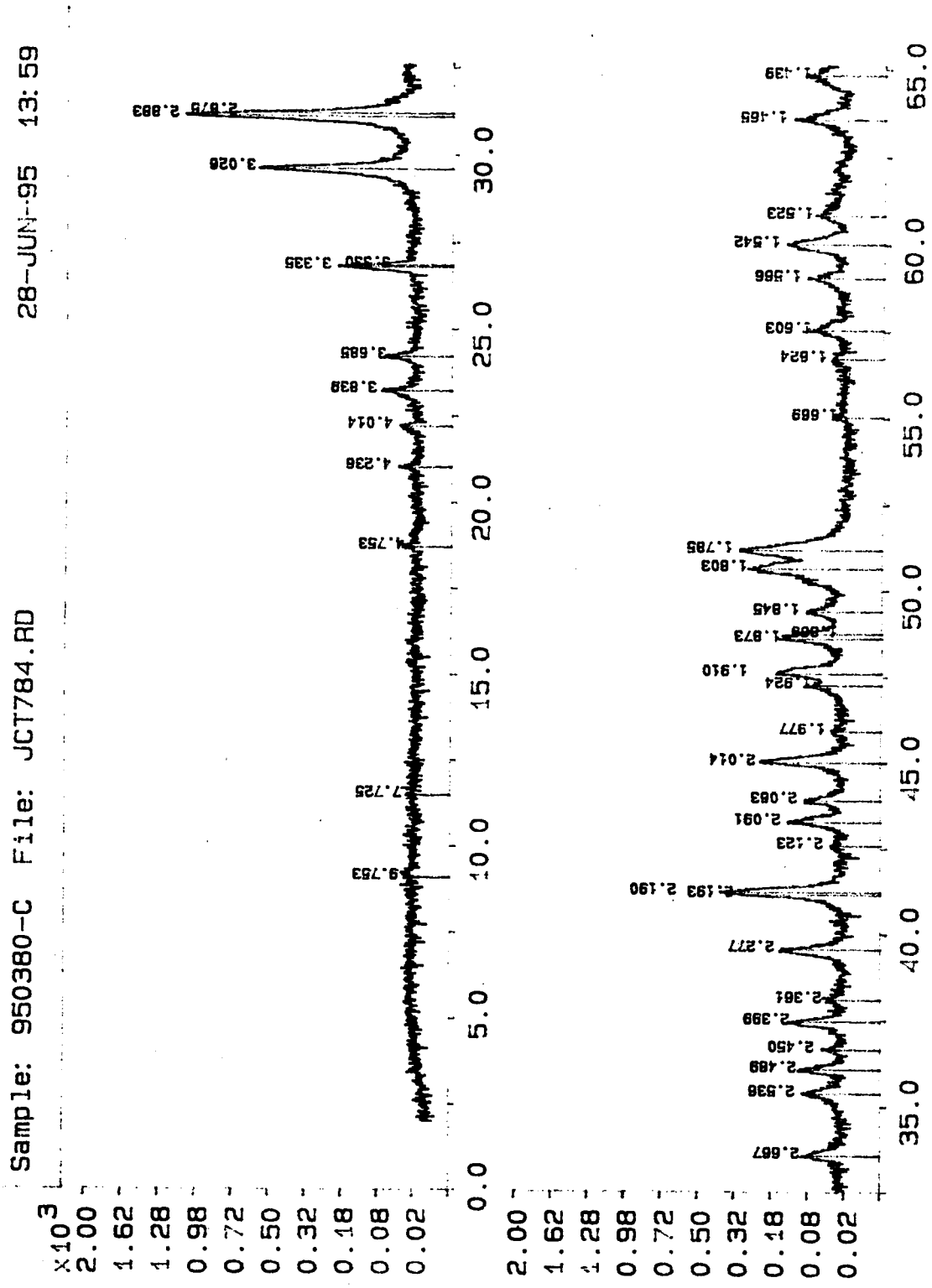


Figure B-34. X-ray diffraction patterns for Sample 950380C

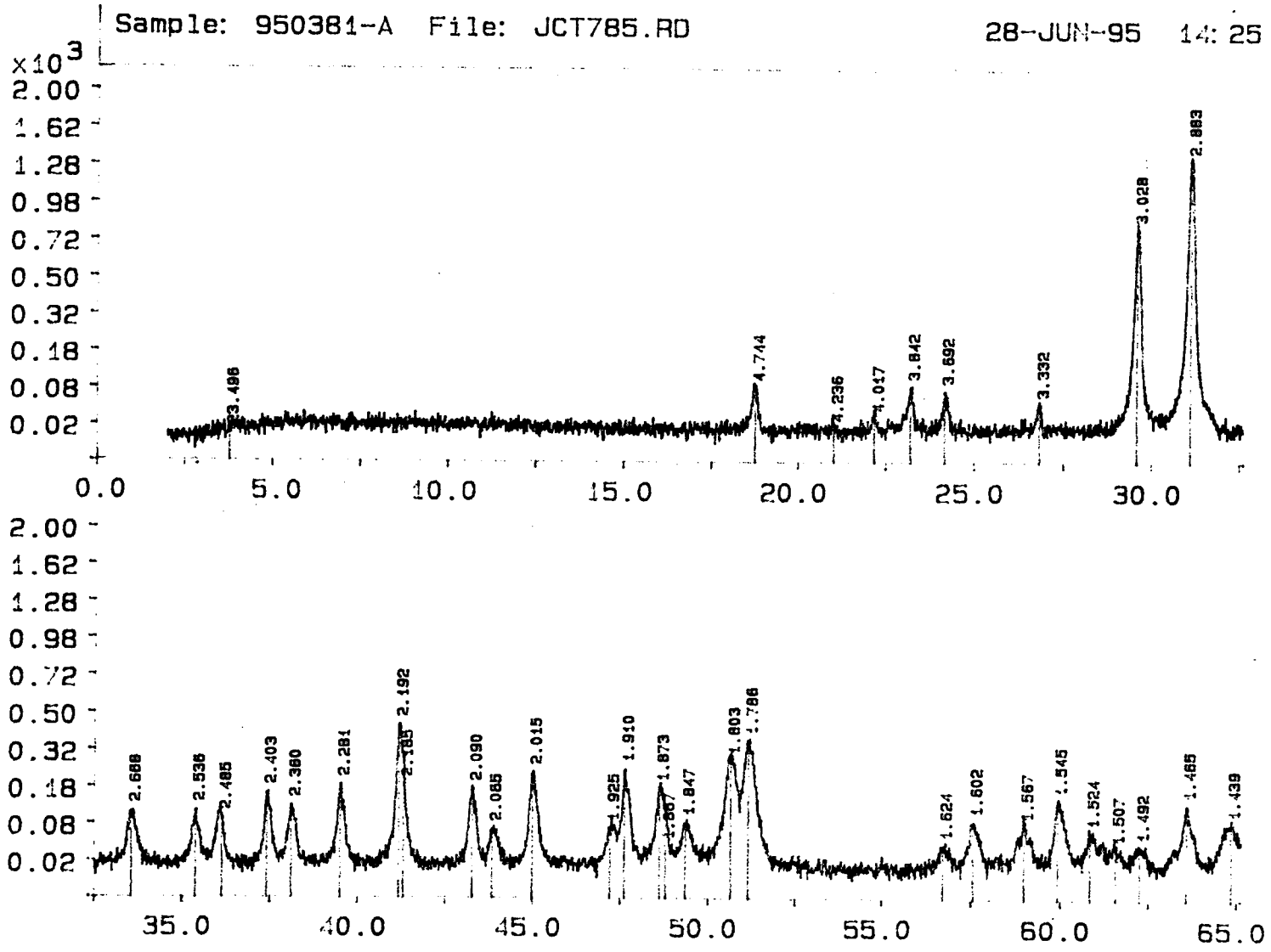


Figure B-35. X-ray diffraction patterns for Sample 950381A

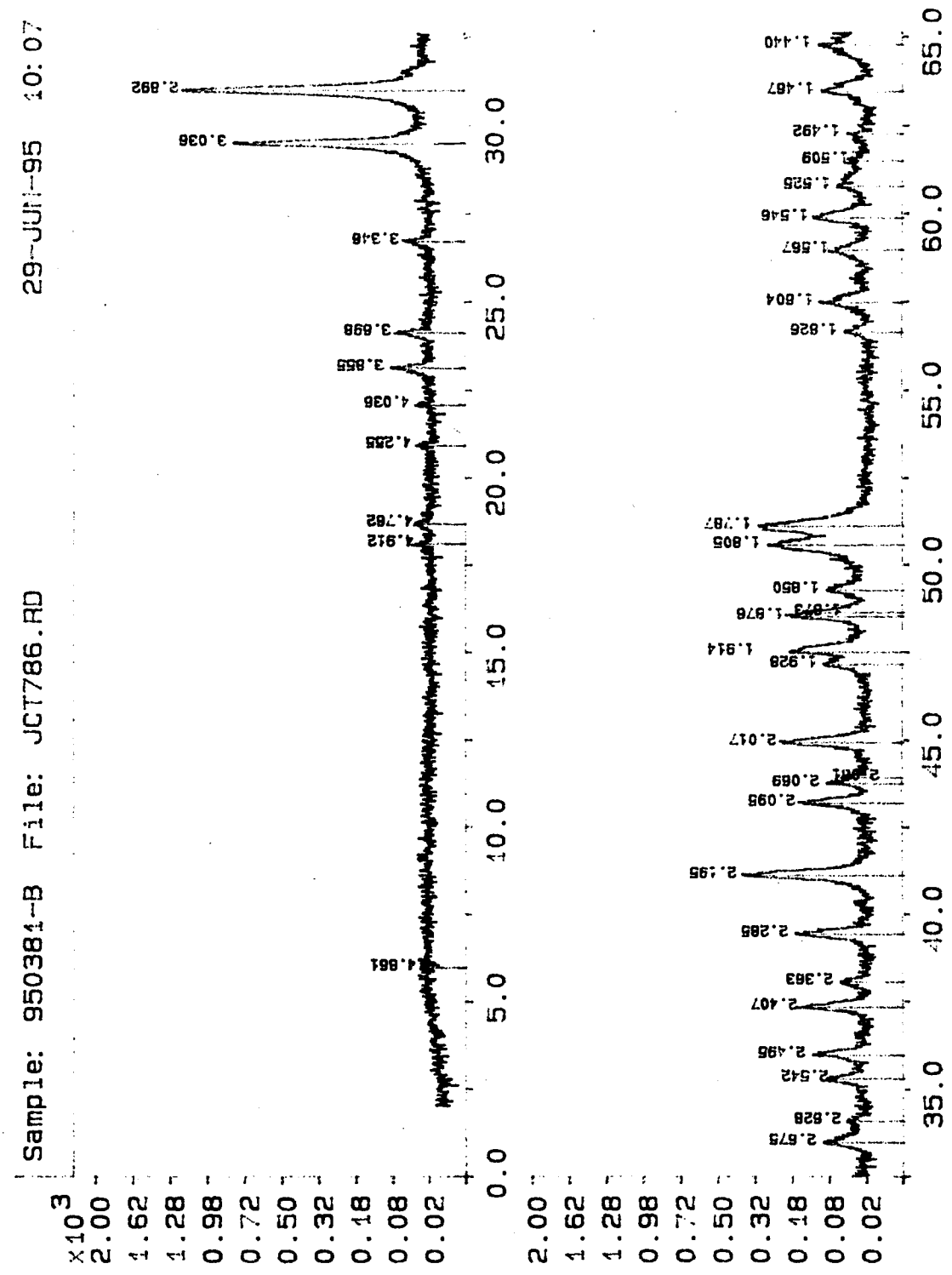


Figure B-36. X-ray diffraction patterns for Sample 950381B

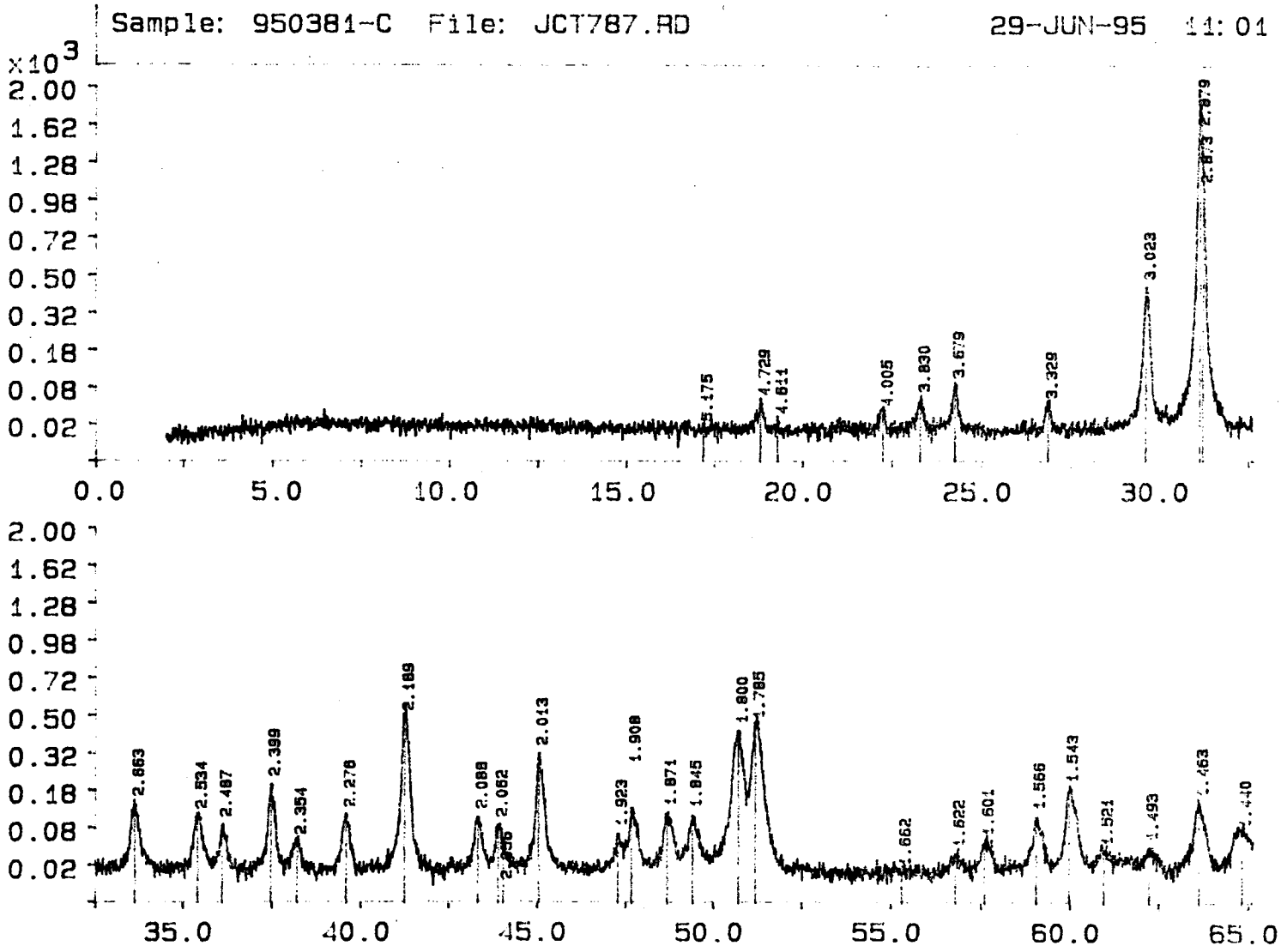


Figure B-37. X-ray diffraction patterns for Sample 950381C

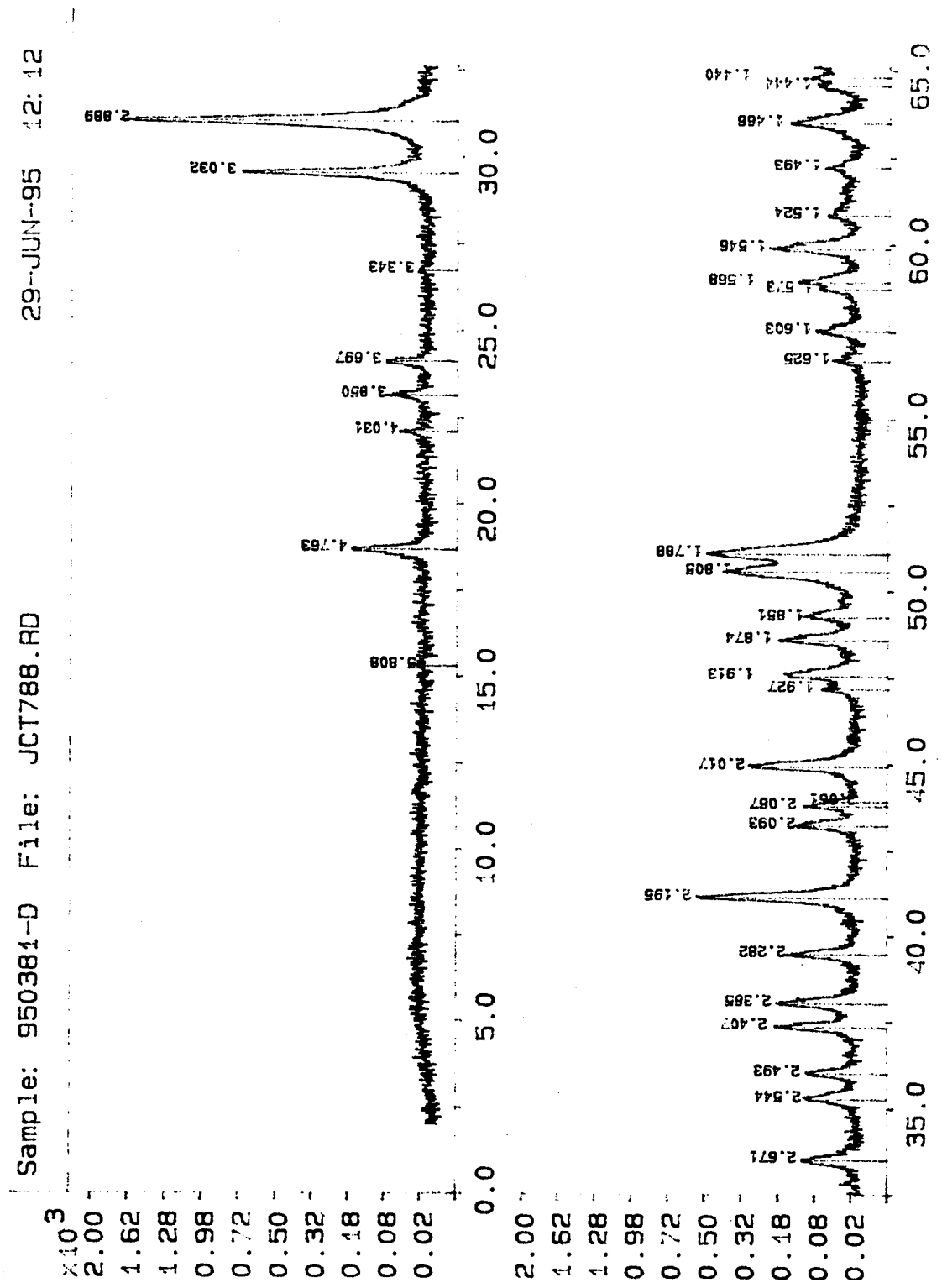


Figure B-38. X-ray diffraction patterns for Sample 950381D

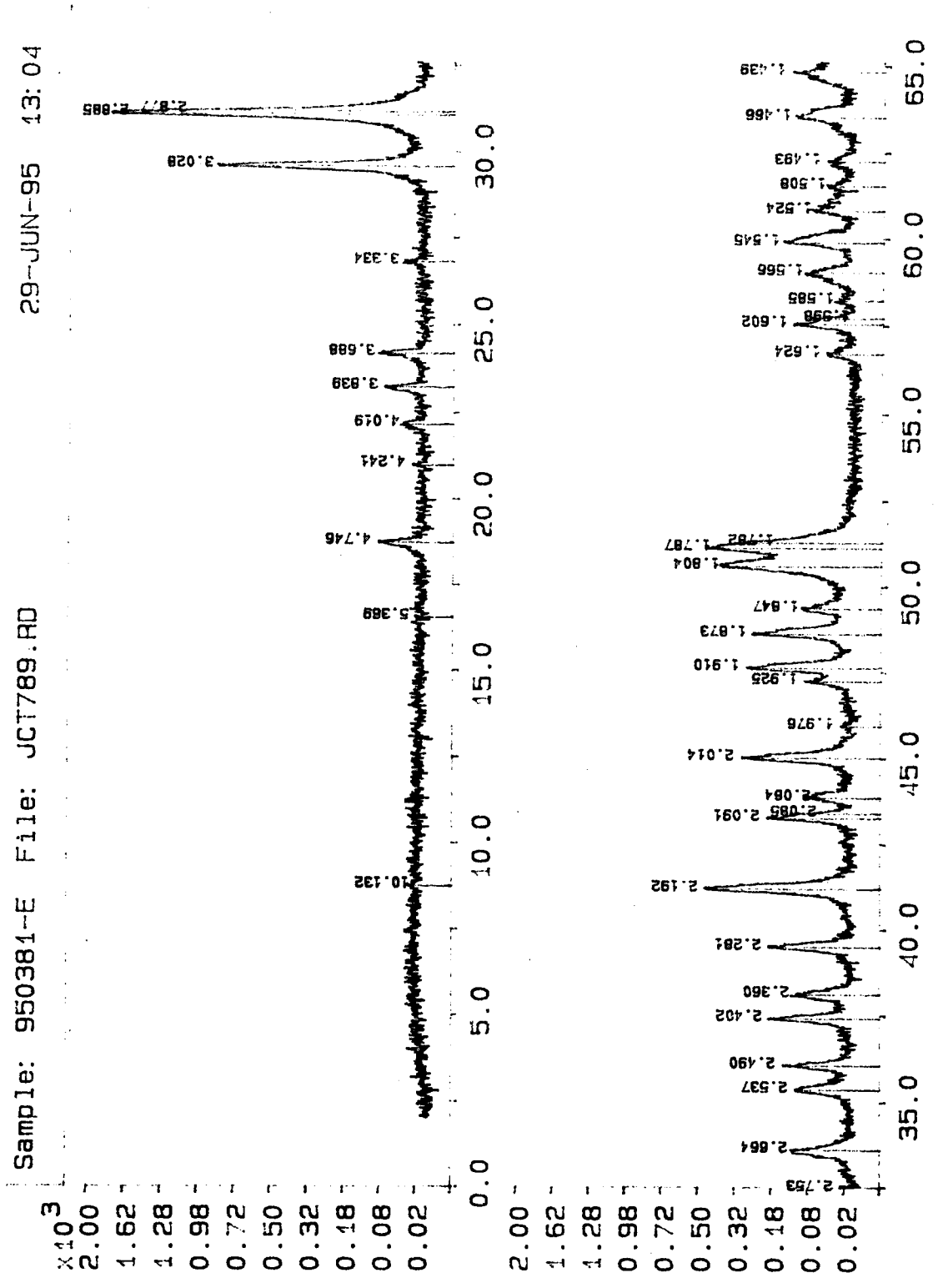


Figure B-39. X-ray diffraction patterns for Sample 950381E

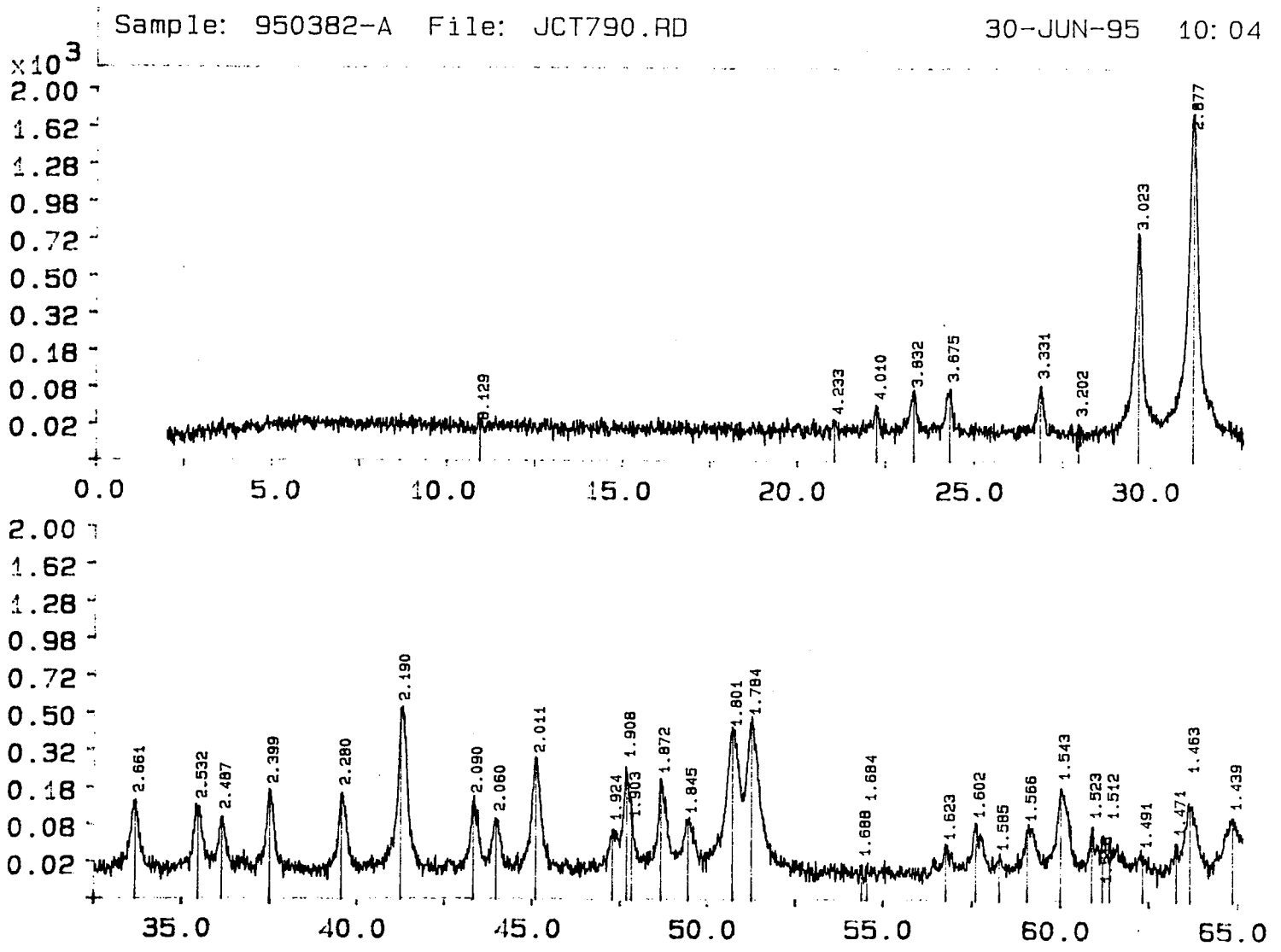


Figure B-40. X-ray diffraction patterns for Sample 950382A

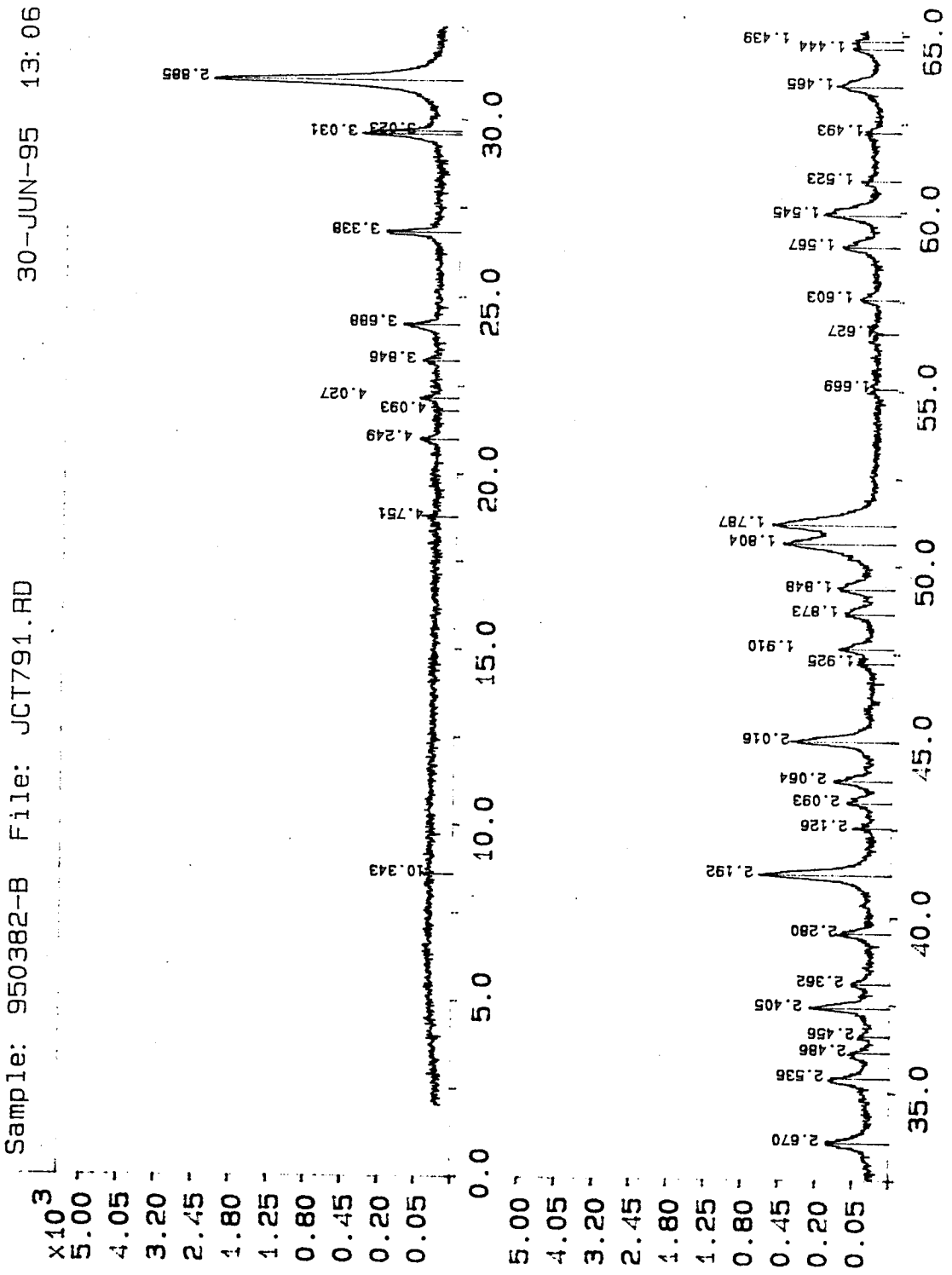


Figure B-41. X-ray diffraction patterns for Sample 950382B

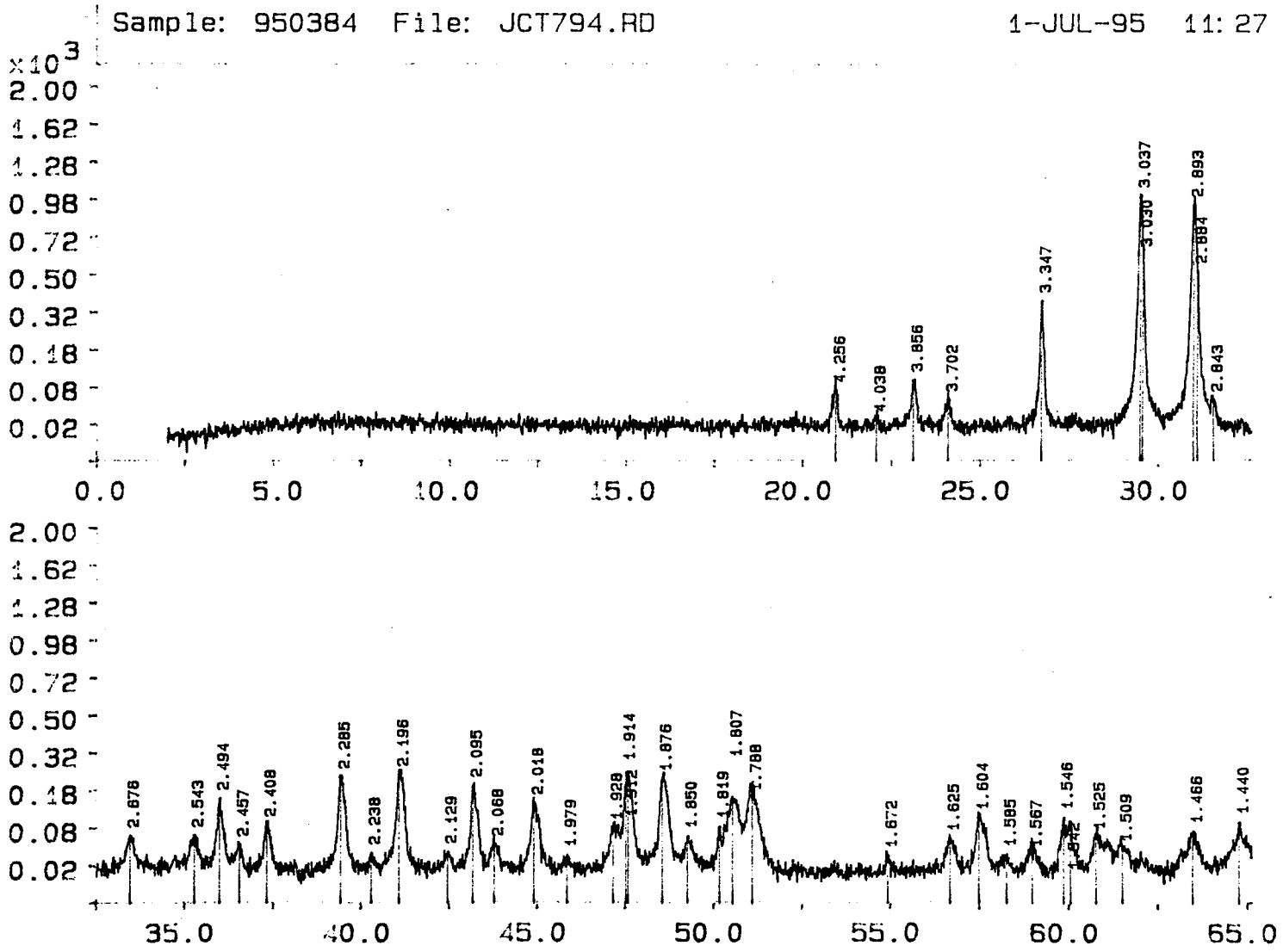


Figure B-42. X-ray diffraction patterns for Sample 950384

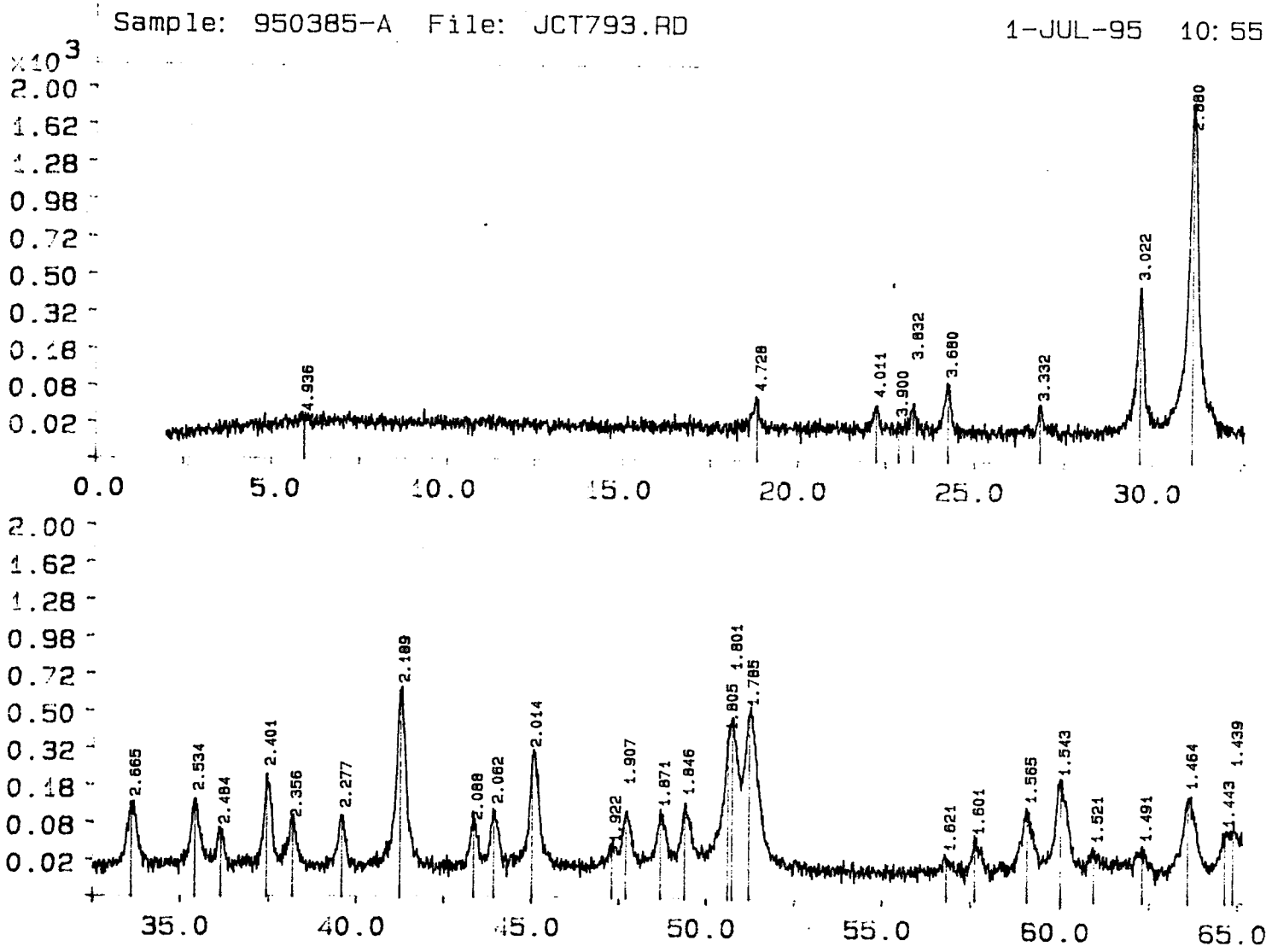


Figure B-43. X-ray diffraction patterns for Sample 950385A

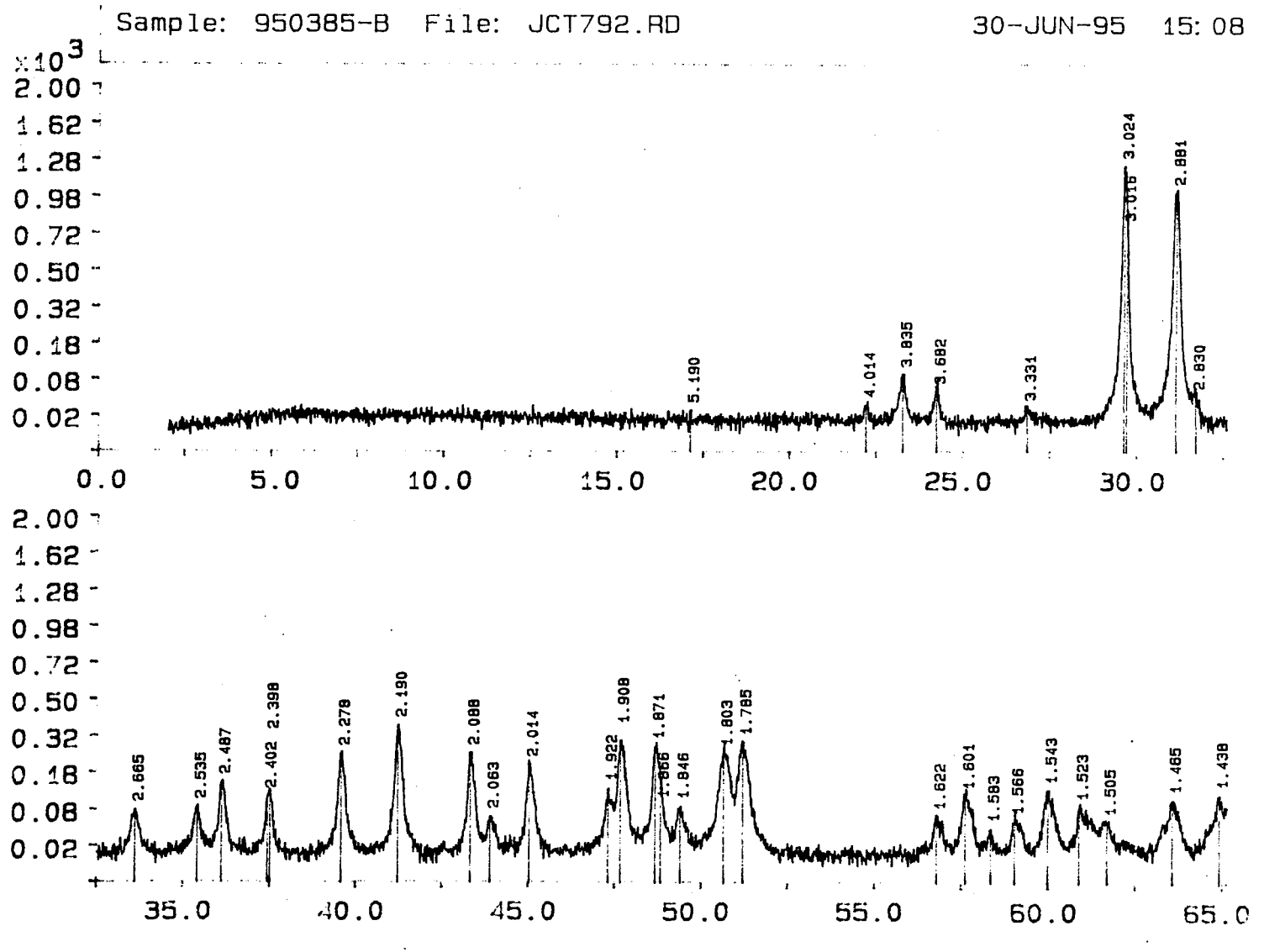


Figure B-44. X-ray diffraction patterns for Sample 950385B

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY *(Leave blank)*	2.REPORT DATE	3.REPORT TYPE AND DATES COVERED
	December 1995	Final report

4.TITLE AND SUBTITLE
Evaluation of Concrete Seawalls at Perry's Victory and International Peace Memorial

5.FUNDING NUMBERS

6.AUTHOR(S)
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7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper
SL-95-5

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207-3199

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT ***(Maximum 200 words)***

The U.S. Army Engineer Waterways Experiment Station was requested in the spring of 1995 to evaluate the concrete in the seawalls at Perry's Victory and International Peace Memorial located on South Bass Island at Put-In-Bay, Ohio, in Lake Erie and to report the cause(s) and extent of concrete deterioration an proposed remedial procedures.

A visual and photographic examination of accessible concrete surfaces was performed, ultrasonic pulse velocity measurements made across the top portion of walls, and cores taken from the tops of seawalls in both distressed and nondistressed areas.

It was concluded that the lack of the resistance of the concrete to freezing and thawing while critically saturated was the major contributor to the observed distress and deterioration in the concrete. This conclusion was based on the air-void spacing factor found in core specimens being near or outside the critical limit where the concrete would be considered protected and the presence of some aggregate particles that are susceptible to damage due to freezing and thawing.

All joint seals showed varying degrees of damage, deterioration, and adhesive and cohesive failures. At a few joints, the seal and filler materials were completely missing.

(Continued)

14.SUBJECT TERMS
Air-void spacing factor
Distressed and deteriorated concrete
Freezing and thawing deterioration
Photographic examination
Ultrasonic pulse velocity measurements

15.NUMBER OF PAGES
134

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

13. (Concluded).

It was recommended that the distressed and deteriorated concrete at 48 locations be considered for removal and replacement. Because of the inadequate air-void system within the remaining concrete, it was recommended that a breathable sealer be applied to monolith faces and reapplied periodically. It was also recommended that existing seals be removed and new seals installed at all joints.

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